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THE ACCESSORY SINUSES OF THE NOSE

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THE ACCESSORY SINUSES OF THE NOSE

THEIR SURGICAL ANATOMY AND THE DIAGNOSIS AND TREATMENT OF THEIR INFLAMMATORY AFFECTIONS

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WITH FORTY PLATES AND EIGHTY-ONE FIGURES

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TO MY FATHER

I DEDICATE

THIS VOLUME

PREFACE

In the year 1898, I was asked by Sir John Struthers, the late President, and by the Council of the Royal College of Surgeons of Edinburgh, to deliver a lecture before the Fellows of the College. I selected for my subject, "The Illumination of the Air Sinuses of the Skull, with some Observations upon the Surgical Anatomy of the Frontal Sinuses." This was in part published in the *Edinburgh Medical Journal* for April and May 1898. In 1899, the Council of the Royal College of Surgeons of Edinburgh awarded me the Surgical Prize for an Essay upon "The Racial Characteristics of the Frontal Sinuses, based upon an examination of 578 skulls."

The subject matter contained in these communications forms the basis of the present volume, in the preparation of which I have included additional observations on the surgical anatomy of the Maxillary Sinus, the Ethmoidal Cells, the Sphenoidal Sinus, and the communications existing between these cavities and the nasal chambers. Two chapters have also been added dealing with the diagnosis and treatment of the Inflammatory Affections of the Nasal Accessory Sinuses.

For the purpose of carrying out these investigations, I have had placed at my disposal from various sources a considerable amount of very valuable anatomical material. My father, Sir William Turner, has allowed me free access to the fine series of crania collected by him, and now contained in the Anatomical Museum of the University of Edinburgh. Without

this privilege, it would have been impossible for me to have carried out this investigation along the lines which I have followed, and my best thanks are due to him for giving me the opportunity to study this important collection.

To Mr. Charles W. Cathcart, F.R.C.S., formerly Conservator of the Museum of the Royal College of Surgeons of Edinburgh, and to the Museum Committee of the College, I feel much indebted for permission to examine the human crania in that museum.

The illustrations, 81 in number, have been made partly from drawings and partly from photographs of original dissections. Several illustrations are from dissections which were kindly lent to me by Professor Symington of Belfast. I am greatly obliged to him for the use of these valuable preparations. The drawings have been carefully executed, under my immediate supervision, by Mr. William Cathie.

My study of the clinical aspect of Transillumination of the Air Sinuses has been greatly assisted by the kindness of Dr. P. M'Bride, who has always allowed me to make use of his clinical material, and to whom I offer most cordial thanks for granting me access to the cases in his wards.

In conclusion, I wish to acknowledge my indebtedness to my friend Dr. Brown Kelly of Glasgow, for many valuable suggestions, and for the time and labour which he has given to the revision of the proof-sheets.

A. LOGAN TURNER.

EDINBURGH, *October* 1901.

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THE
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CHAPTER I

THE OUTER WALL OF THE NASAL CAVITY AND THE MAXILLARY SINUS

IN order that the clinical phenomena met with in cases of inflammatory affections of the accessory nasal sinuses may be readily understood, the surgeon should possess a thorough knowledge, not only of the air cavities, but of the anatomy of the outer wall of each nasal chamber. This is studied to the greatest advantage with the vascular mucous membrane *in situ*. In the macerated skull the contour of the parts is considerably altered, and the size and relations of the various openings leading from the air sinuses into the nose, when the bones are divested of their mucous covering, present a different appearance to that seen when covered by mucous membrane.

The nose consists of two chambers which open anteriorly on the face at the nostrils, and which communicate posteriorly through the posterior nares or choanæ with the naso-pharynx. The two chambers are separated from each other by a mesial vertical septum, composed in its greater part of the central plate of the ethmoid bone, the vomer, and the septal cartilage. The septum, which forms the inner wall of each chamber, is frequently deviated to one or other side of the mesial plane,

sometimes to a considerable degree, more especially in its anterior cartilaginous part. Frequently, too, it presents a well-marked ridge, running antero-posteriorly but somewhat obliquely upwards and backwards for a short distance above the floor of the nasal cavity (Plate I.). The septum is covered by the nasal mucous membrane.

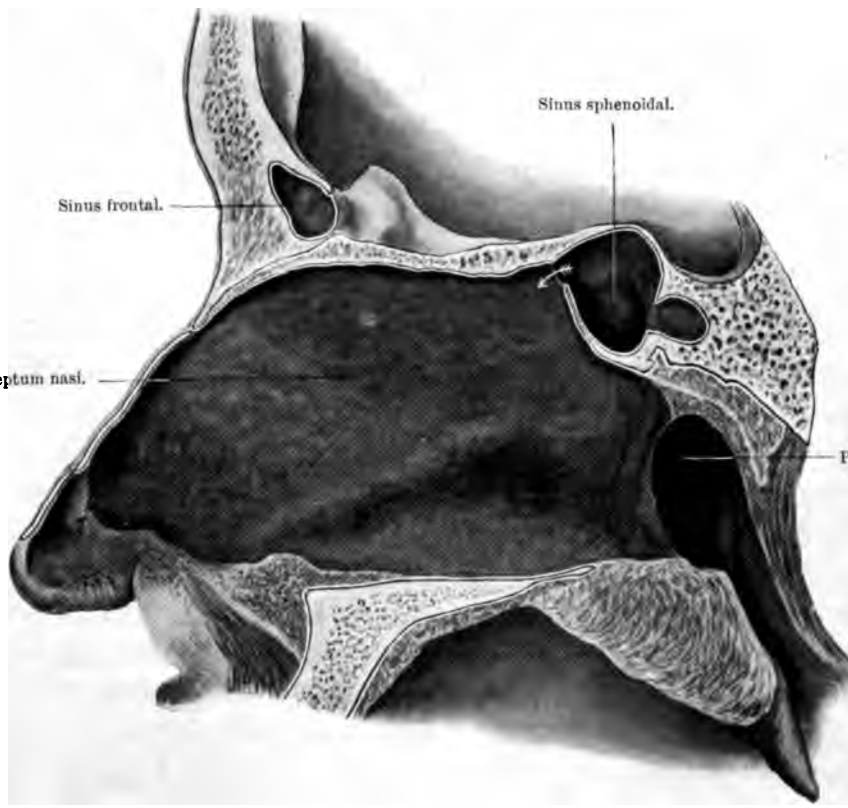
The *roof* of each cavity, which is very narrow, is formed anteriorly by the nasal bone, and the nasal spine of the frontal bone, both of which are directed downwards and forwards; its central portion consists of the cribriform plate of the ethmoid bone, which lies horizontally; while, posteriorly, the roof has a downward and backward inclination, and is formed partly by the sphenoidal spongy bone or anterior wall of the sphenoidal sinus, and in part by the inferior surface of the body of the sphenoid bone (Plate I.).

The *floor* of the nose is formed from before backwards by the palatal plates of the superior maxillary and palate bones.

The *outer wall* of each chamber is very irregular, and has opening on it the frontal, ethmoidal, superior maxillary, and sphenoidal air sinuses. A more detailed description of its appearance and character is therefore necessary. In front the bony wall is composed of the nasal process of the superior maxilla with the posterior margin of which the lachrymal bone articulates. In the middle region is the lateral mass of the ethmoid bone above, with the inner surface of the body of the superior maxilla and the inferior turbinated bone at a lower level. Posteriorly, the vertical plate of the palate bone and the internal pterygoid plate of the sphenoid complete the outer nasal wall. Its surface is covered by mucous membrane.

The irregularity in the outer wall of the nasal cavity is due to a convoluted arrangement of bone known as the *superior*, *middle*, and *inferior turbinated bones* (*conchae*

PLATE I.



Dissection to show the nasal septum (left side). The relation of the sphenoidal sinus to the roof of the nose and to the posterior naris is also shown.

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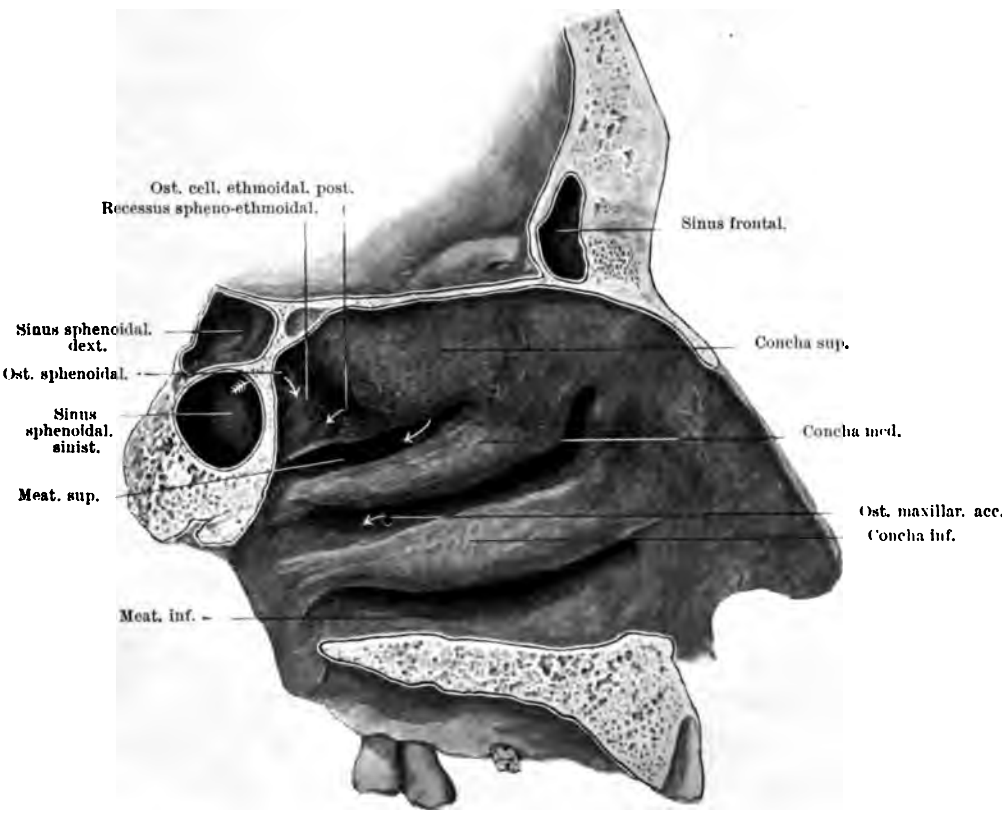
PLATE II.



The outer wall of the left nasal chamber. The arrows indicate the position of the ostia that may be seen without any dissection. The relation of the accessory maxillary ostium to the inferior turbinated body is well seen.

[*To face page* 3.

nasi) (Plate II.). The first two constitute the inner surface of the lateral mass of the ethmoid, and hence are designated the ethmo-turbinated bones. The inferior turbinated, on the other hand, is a distinct bone, articulating mainly with the superior maxilla; for descriptive purposes it may be termed the maxillo-turbinated bone. When the turbinated bones are considered in association with their mucous covering, they are frequently spoken of by clinicians as the turbinated bodies, or turbinals.

Immediately external to the two ethmo-turbinals is a number of air-filled spaces or sinuses, which make up a large portion of the lateral mass of the ethmoid, and which are named the ethmoidal air cells. The inferior ethmo-turbinal, *i.e.* the middle turbinated body, has a free lower border, and the anterior end of the free portion is sometimes hollowed out into a small air space called the turbinal cell (*concha bullosa*), which communicates with the middle meatus. This cell, however, may be absent upon one or both sides of the nose (Plate III.).

The space which intervenes between the inner or mesial surface of the middle turbinated body and the nasal septum is called the olfactory cleft (*sulcus olfactorius*) (Plate III.).

Each turbinated body overhangs a well-marked channel or meatus, named according to the bone which lies immediately above it—the *superior*, *middle*, or *inferior meatus* of the nose (Plate II.).

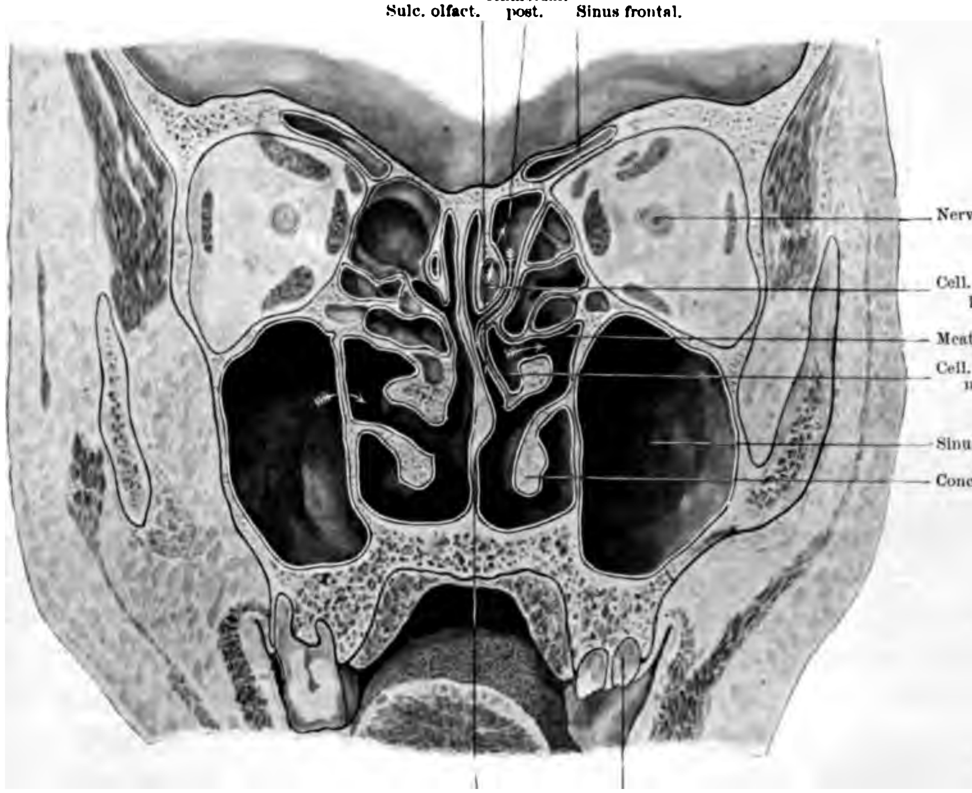
These channels correspond in length to the turbinated bodies beneath which they are situated. The superior meatus, or *incisura ethmoidalis inferior*, is confined to the posterior third of the outer nasal wall, its anterior end terminating in a *cul-de-sac*. The middle meatus commences at the posterior naris, and runs forwards for about two-thirds of the extent of the nasal wall; although it does not reach the anterior naris, it is visible from that opening. The inferior meatus, in relation

to the floor of the nose, extends from the anterior to the posterior naris. Not infrequently a fourth and smaller channel lies above and parallel to the superior meatus, described under the term *incisura ethmoidalis superior* (Plate II.).

Situated above the superior meatus, and forming the interval between the posterior extremity of the superior turbinal and the anterior aspect of the body of the sphenoid, is a shallow but well-defined triangular fossa, named the spheno-ethmoidal recess (*recessus spheno-ethmoidalis*) (Plates II. and XXII.). This recess, though subject to some variation both in its vertical and transverse diameters, forms a distinct depression upon the upper and posterior aspect of the outer nasal wall.

Considerable importance must necessarily be attached to these meatuses, from the fact that the accessory nasal sinuses communicate through them with the nasal chamber. Before considering the manner in which these communications are effected, it is necessary to describe the situation and general relations of the following cavities—the maxillary sinus, the frontal sinus, the anterior and posterior ethmoidal cells, and the sphenoidal sinus. These air spaces, both on anatomical and clinical grounds, may be conveniently considered as forming two groups — first, the anterior group, consisting of the maxillary and frontal sinuses and the anterior ethmoidal cells; secondly, the posterior group, containing the posterior ethmoidal cells and the sphenoidal sinus. This anatomical grouping—the clinical significance of which will be afterwards apparent—is based upon the relative positions of the orifices of these cavities. The air sinuses of the anterior group communicate with the middle meatus below the line of origin of the middle turbinated body, while those of the posterior group open into or above the superior meatus—that is, above the level of the middle turbinate. We shall commence with a description of the maxillary sinus.

PLATE III.



Drawing from a frozen section, kindly lent to the author by Prof. Symington. The vertical coronal **section through both nasal** chambers and maxillary antra is made on the plane of the first molar **teeth, and is viewed from in front.** On the right side an arrow indicates the position of an accessory **maxillary ostium. On the left side** the posterior ethmoidal cells are seen opening into the olfactory **cleft and a middle turbinal** cell into the middle meatus. The section also shows the frontal sinuses **extending for a** considerable distance backwards along the roof of the orbit.

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THE MAXILLARY SINUS (SINUS MAXILLARIS) OR ANTRUM OF HIGHMORE.

The maxillary sinus is a cavity of varying dimensions, which is constantly present in the body of the upper jawbone.

Development of the Maxillary Sinus (Plate IV.).—At birth the antrum exists merely as a slit-like indentation upon the outer wall of the nasal chamber. It presents the following measurements, which are based upon an examination of six upper jawbones taken from new-born children :—The vertical diameter = 3 mm., the transverse diameter = 2 mm., and the antero-posterior diameter = 7 mm. At this period the body of the superior maxilla is made up almost entirely of the alveolar process of the jaw, the sockets of the teeth being almost in contact with the orbital plate of the maxilla forming the floor of the orbital cavity. There is, therefore, at birth no maxillary sinus beneath the orbit. The growth of the body of the upper jawbone, and with it an increase in the size of the face, takes place by the formation of a mass of cancellous or spongy bone between the alveolar process and the orbital plate of the maxilla. In this way the alveolar process along with the teeth becomes separated from the orbital plate. Coincident with the increase in the cancellous tissue upon the facial and dentary aspects of the bone, a process of absorption apparently takes place upon its nasal and orbital surfaces, thus causing an increase in the size of the antrum. This simultaneous process of growth and absorption continues until the eruption of the third permanent molar or wisdom tooth, at or about the twenty-fifth year of life. At that time the antrum reaches its complete or adult form. If we compare the development of the maxillary sinus with Symington's description[1] of the development of the mastoid

[1] *Edin. Med. Journ.*, October 1886.

air cells in the child, a striking similarity between the two processes is apparent.

These facts are illustrated on Plate IV. Fig. 1 is from a drawing showing the left maxillary sinus in a new-born child, as seen from the nasal aspect. The remaining figures are vertical, transverse sections through the floor of the right nasal chamber and the right maxillary sinus on the plane of the malar process. Fig. 2, taken from the upper jawbone of a new-born child, shows the absence of the body of the maxilla, the tooth sockets being separated from the orbital plate by a very thin layer of somewhat compact bone. At this period there is no extension of the antrum beneath the orbit. Fig. 3 illustrates a similar section through the upper jawbone of a child during the period of temporary dentition. The body of the jaw consists of a mass of cancellous bone separating the alveolus from the orbital plate; the antral cavity is considerably enlarged, and extends outwards beneath the orbit as far as the infra-orbital canal. Its transverse diameter measures 5 mm., while its vertical measurement is 8 mm. Fig. 4 is the transverse section of the superior maxilla in an adult, on the plane of the second molar tooth, showing an antral cavity of considerable dimensions. The cancellous bone has been entirely absorbed even in the alveolar process, and the cavity of the antrum extends into the malar process of the upper jaw. In this case the cavity measures 1 in. transversely and 1¼ in. in a vertical direction.

In the adult the antrum may be described as having a roof, a floor, and three walls. Its *roof* is a thin plate of bone which on its upper aspect forms the floor of the orbit. The infra-orbital canal, which transmits the superior maxillary nerve and infra-orbital vessels as they pass to the face, lies in the roof of the cavity; it sometimes appears as a well-marked ridge which projects into the cavity in the angle between the roof and the facial

PLATE IV.

FIG. 1.—The left superior maxilla of a new-born child, viewed on its nasal aspect.

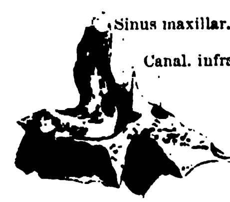

FIG. 2.—Vertical transverse section through the right superior maxilla of a new-born child, viewed from behind. The antrum is a mere recess on the nasal aspect of the bone, and the teeth sockets lie almost in contact with the floor of the orbit.

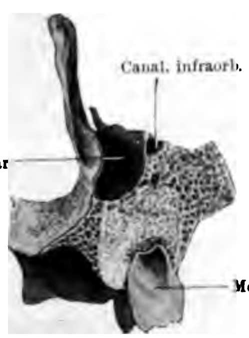

FIG. 3.—Vertical transverse section through the right superior maxilla during the first dentition, on the plane of the second molar tooth. The antrum, viewed from behind, is small, and the body of the maxilla consists mainly of cancellous bone.

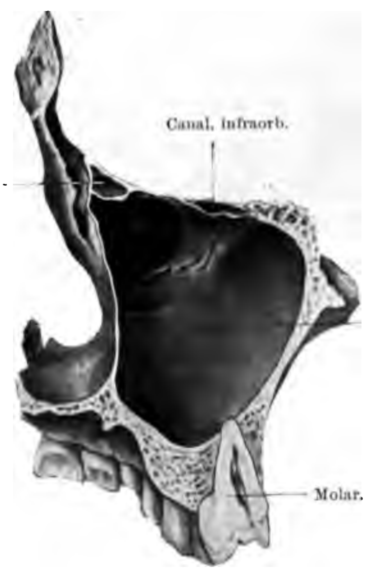

FIG. 4.—Vertical transverse section through the right superior maxilla of an adult, viewed from behind, on the plane of the first molar tooth. The section shows that the cancellous bone is almost entirely absorbed, and that the maxillary sinus has reached its full dimensions. The fang of the tooth projects into the floor of the sinus.

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PLATE V.

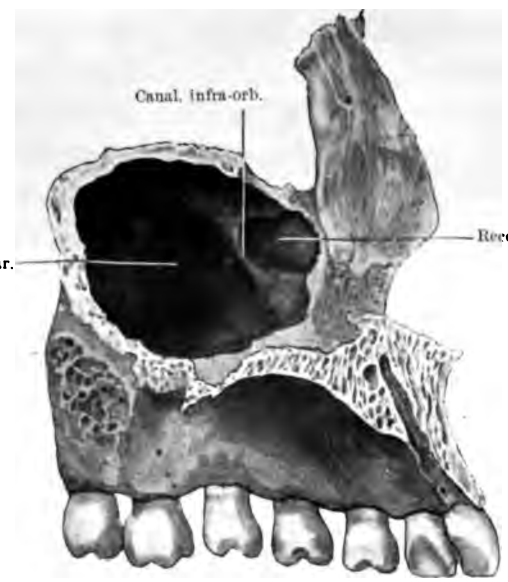

FIG. 1.—Left superior maxilla with nasal wall of maxillary sinus removed. Within the sinus there is seen a well-developed ridge containing the canal for the superior maxillary nerve and vessels.

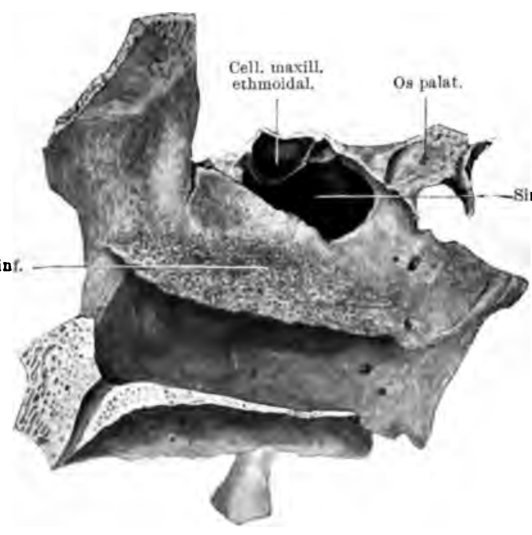

FIG. 2.—Right superior maxilla viewed on its nasal aspect, with inferior turbinated bone and portion of palate bone, and pterygoid process of sphenoid bone attached. A partial view is obtained into the maxillary sinus, showing a maxillo-ethmoidal cell under the roof of the antrum.

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wall (Plate V. Fig. 1). The occasional presence of a defect in the osseous wall of this canal may afford a possible explanation in some cases of the neuralgic pains which may be met with in antral suppuration. Care should be exercised when curetting the interior of the cavity in this situation, lest the thin layer of bone and the nerve protected by it be injured. A pocket or recess between the projection thus formed, and the roof of the cavity, may be overlooked by the surgeon when scraping the sinus; in this way an area of diseased mucous membrane may be left untouched. In some specimens the ethmoidal border of the orbital plate of the superior maxilla, which forms the roof of the antrum, is divided into two tables separated by one or more air cells, which complete certain air cells of the ethmoid. Hence these spaces, which vary somewhat in number, may be suitably described as maxillo-ethmoidal cells (Plate V. Fig. 2). In the event of the bone which forms the inferior boundary of the maxillo-ethmoidal cells giving way in the course of a chronic suppuration in the ethmoid labyrinth, the maxillary sinus would readily become infected.

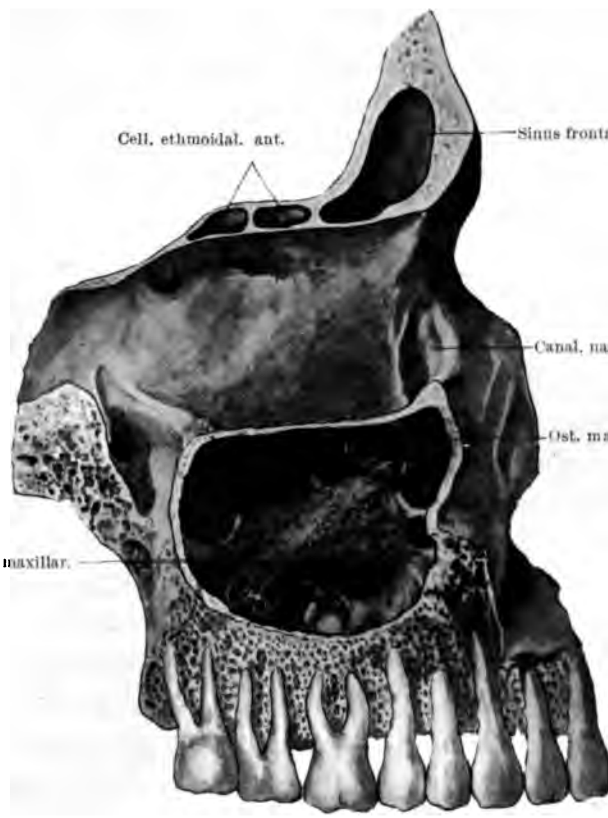
The *floor* of the sinus is formed by the alveolar or dentary border of the superior maxilla, and consequently bears an important relation to the teeth and their sockets. In a cavity of average dimensions the floor lies in the same horizontal plane as the floor of the nasal chamber. The layer of spongy bone between the roots of the teeth and the floor of the cavity varies in thickness in different skulls and sometimes upon the two sides of the same skull. It is possible that secondary infection of the sinus from a diseased tooth may be to some extent dependent upon the thickness of this layer of intervening bone. Direct communication between the root of a tooth and the mucous membrane of the cavity, due to defects in the bone, is not often met with; but not infrequently small elevations are formed on the floor of the sinus by the pro-

jecting tooth fangs covered with a thin layer of bone. The osseous floor is, as a rule, thinnest above the socket of the first and second molar teeth, so that, in the operation of opening the sinus through the alveolus, the perforator meets with least resistance in these situations. The relation of the teeth to the sinus is of great practical importance, and, owing to the variations which occur in the size of the cavity, the relationship is not a constant one (Plate VI.). When the cavity is of unusual size, the canine root lies below the floor of the sinus, but this is a very exceptional condition. Occasionally the perforator will enter the antrum when the socket of the first bicuspid is pierced. The second bicuspid and the three molars, when the cavity is of ordinary dimensions, are in relation to it, but in a considerable proportion of cases the second bicuspid lies just in front of the floor of the sinus. In an unusually small cavity, on the other hand, I have seen only the second and third molars in relation to the floor (Plate VIII.). Bearing in mind, therefore, what possible exceptions may arise, we find that the three molar teeth maintain the most constant relation to the floor of the antrum, while the second bicuspid comes next in frequency.

The *posterior wall* of the maxillary sinus is a thin plate of bone which forms the anterior boundary of the zygomatic fossa.

The *inner* or *nasal wall* of the antrum is clinically of considerable importance, and can only be properly studied when the mucous membrane is in place. For purposes of description it is convenient to consider the nasal wall as subdivided into an upper and a lower part by the inferior turbinated bone. That portion of the wall which lies below the attachment of this bone consists of a thin osseous plate which forms the outer boundary of the inferior meatus of the nose. This plate is thinnest immediately below the attachment of the turbinate, and in that situation offers the

PLATE VI.



Dissection showing the right maxillary sinus opened upon its outer aspect. The ostium maxillare is seen situated immediately below the roof of the cavity. The outer table of bone is removed in order to show the relation of the fangs of the teeth to the floor of the antrum. Anterior ethmoidal cells are seen passing into the roof of the orbit behind the frontal sinus.

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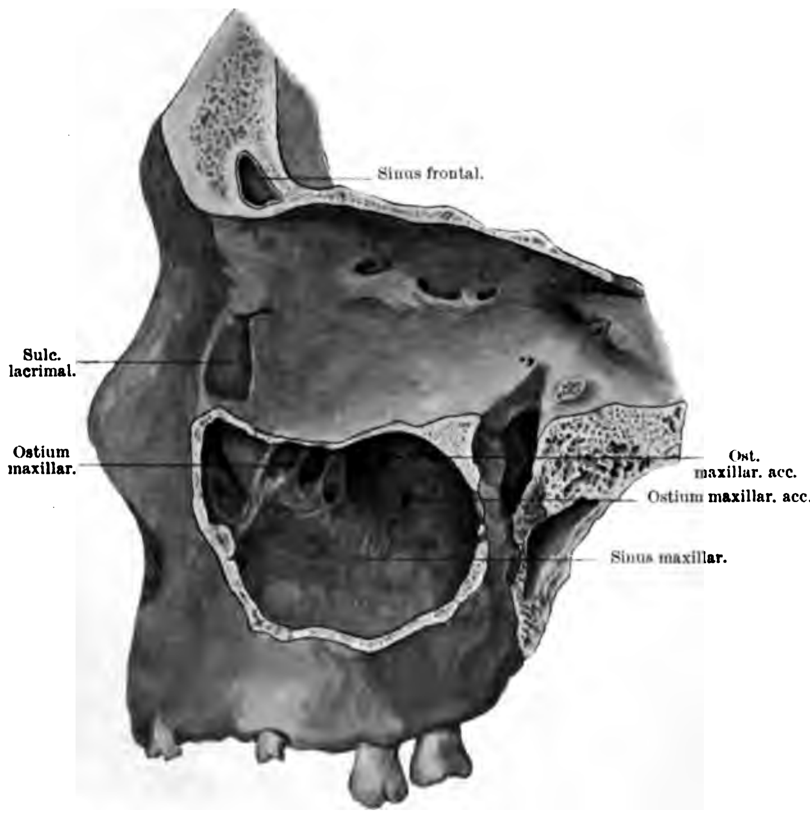
Plate VII.



Dissection showing interior of left maxillary antrum. Behind the ostium maxillare are two small accessory openings situated in the membranous part of the nasal wall of the sinus.

[To face page 9.

least resistance to exploratory puncture of the sinus. Further, when the antrum is small, by choosing this site, there is less likelihood of the operator missing the cavity altogether, as might be the case if the puncture were attempted nearer the nasal floor. Sometimes this part of the wall bulges into the antrum, and diminishes the size of that cavity. Above the plane of the inferior turbinated bone the nasal wall is partly osseous, but mainly membranous, where it forms the outer wall of the middle meatus. In this region is situated the orifice of the antrum, the *ostium maxillare*, the margins of which are partly osseous and partly membranous. This aperture permits of communication between the antrum and the channel of the infundibulum to be subsequently described (see Plates XXI. and XXIII.): it lies immediately beneath the roof of the antral cavity, a position which consequently does not permit of free drainage being maintained between that cavity and the nasal chamber, in inflammatory affections of the former.

The maxillary ostium, usually somewhat oval in shape, varies in size; it may present a vertical diameter of 2, 4, or even 6 mm., whilst the antero-posterior diameter may measure from 3 to 9 or even 18 mm. Sometimes an additional opening (*ostium maxillare accessorium*) is present in the membranous portion of the nasal wall (Plate VII.). According to the observations of Giraldès [1] and Zuckerkandl,[2] this accessory opening occurs in about 10 per cent. of cases. I have myself seen it four times in nine dissections, which indicates the probability of even a larger percentage than the above. In one of my cases there were two of these openings in the membranous part of the wall (Plate VII.). The accessory opening varies in size from that of a small pin-head to an aper-

[1] *Virchow's Archiv.*, Bd. ix. 1856.

[2] "Normale u. Pathologische Anatomie der Nasenhöhle u. ihrer pneumatischen Anhänge," Wien, 1893.

ture having a vertical diameter of nearly 8 mm. or more; it may indeed be larger than the constant or infundibular orifice. The accessory opening situated above the posterior half of the inferior turbinated body communicates directly with the middle meatus posterior to and at a lower level than the ordinary ostium. Consequently, when it is present, the secretion from the antral cavity will drain away more readily and tend to pass backwards into the naso-pharynx. This anatomical fact serves to explain those cases in which the discharge from the sinus passes mainly into the throat. The relations of these openings to the outer wall of the nasal cavity are dealt with in greater detail in Chapter V.

The *anterior* or *facial wall* is thin: close to its upper margin, but subject to slight variations in position, is the foramen transmitting the infra-orbital nerve and vessels (Plate VIII. Fig. 1). Care must be taken to avoid injury to these structures when the antrum is freely laid open through the facial wall. The average height of the foramen above the extremities of the teeth roots is 1·3 cm. ($\frac{1}{2}$ in.). The facial wall is limited externally by the prominent malar ridge. In front, this surface is marked by the canine ridge, corresponding to the socket of the canine tooth. In an antrum of average dimensions the outer edge of this latter ridge indicates externally the line of union between the facial and nasal walls of the cavity. Between the canine and malar ridges lies the canine fossa, a depression which varies considerably in depth. Occasionally the facial wall is markedly depressed: the size of the antral cavity thus becomes greatly diminished, and operative procedures are rendered more difficult (Plate VIII. Figs. 1 and 2). Any attempt to open into the sinus through the canine fossa in such a case results merely in perforation of the outer nasal wall. Similarly, if an exploring trocar were directed towards the antrum through the outer wall of the

PLATE VIII.

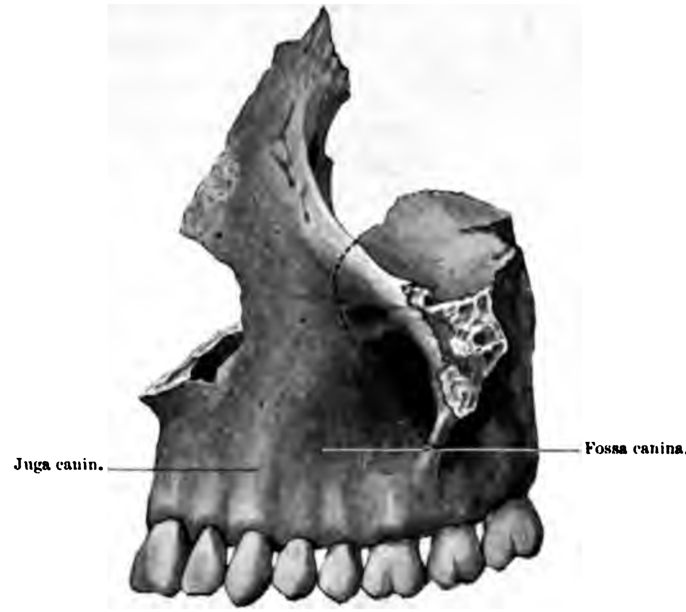


FIG. 1.—Left superior maxilla; the maxillary sinus mapped out by dotted line is very small, owing to the marked depression of the facial wall and a bulging outwards of the nasal wall of the sinus.

FIG. 2.—The same bone as that figured above, viewed on its nasal aspect; the maxillary sinus is mapped out by the dotted line. The right superior maxilla presented the same features as the above.

[*To face page* 10.

inferior meatus, it would penetrate the soft tissues of the cheek, while perforation of the socket of the second bicuspid tooth or of the first molar would result in the instrument piercing the floor of the nose.

The average dimensions of a fully developed maxillary sinus are found to vary somewhat within certain limits. The following figures, obtained in a series of measurements, express the diameters of a cavity of average size :—

The vertical height opposite the first molar tooth, 3·5 cm. (about $1\frac{1}{2}$ in.).

The transverse breadth = 2·5 cm. (1 in.).

The antero-posterior depth, measured just below the roof = 3·2 cm. ($1\frac{1}{4}$ in.).

Variations in the size of the cavity are observed in different skulls and upon the two sides of the same skull. Thus, its diminution may be due to approximation of the facial and nasal walls, as already described, or it may result from defective absorption of the cancellous bone during the period of growth. When the cavity is small from this latter cause, its walls are increased in thickness, so that considerable opposition is met with where the sinus is entered from without. This is seen most markedly in the floor or alveolar border. In a pronounced case of this kind, the floor of the antrum may lie at a considerably higher level than that of the nasal chamber. On the other hand, the sinus may be abnormally large and its walls thin. In such cases only a thin layer of bone separates the teeth from the antrum, the floor of which may lie at a lower level than that of the nose. Occasionally the cavity extends into the palatal plate of the maxilla, so that it thus intervenes between the floor of the nose and the roof of the mouth.

Small pockets and recesses are frequently found, rendering the inner surface of the walls uneven and thus favouring the

collection of abnormal secretions within the antrum. Complete subdivision into two compartments by a vertical or horizontal septum is rare. According to Zuckerkandl,[1] when such cases occur the posterior or superior compartment communicates with the superior meatus of the nose, while the anterior or inferior opens into the infundibulum. The anatomist Wenzel Gruber[2] found a complete subdivision five times in 200 skulls, but in his cases both cavities communicated with the middle meatus. In the presence of this anomaly, surgical exploration of the anterior or inferior cavity might result in failure to find the source of suppuration. I have observed one specimen in which a vertical partition, situated opposite the interval between the second and third molars, almost completely divided the antrum into an anterior and posterior compartment; a small aperture in the septum immediately below the roof of the sinus afforded communication between the two subdivisions.

The antrum is lined by a delicate vascular muco-periosteal layer, continuous through the ostium maxillare with the lining membrane of the middle meatus; its epithelium is ciliated; it contains mucous glands; while its deeper layer serves as a periosteal covering to the inner surface of the bony walls of the cavity. The walls of the sinus are covered on both their outer and inner aspects by a periosteal membrane, so that the bone can obtain a nutritive supply from one aspect should the other be interfered with. It is possible that this anatomical fact may explain the absence of caries of the bone in so many cases of suppuration in the antrum.

[1] *Loc. cit.*
[2] *Virchow's Archiv.*, Bd. cxiii.

CHAPTER II

THE FRONTAL SINUS (SINUS FRONTALIS)

BEFORE giving a detailed account of the frontal sinus, it will not be out of place to briefly indicate the salient points in the anatomy of the frontal bone, in so far as they relate to that cavity. We are able to distinguish in the frontal bone a vertical or frontal portion and a horizontal or orbital part—the former constituting the forehead region of the skull, the latter, the greater part of the roof of the orbits.

As the frontal bone is developed from two centres of ossification, it consists at first of two distinct portions, which articulate with each other by a mesial vertical suture. In the first or second year of life the two halves of the bone unite; the suture usually becomes obliterated, although traces of it not infrequently remain throughout life upon its anterior surface above the root of the nose, as evidence of the original separation. Sometimes, however, this suture persists and forms the condition called *metopism.* The frontal bone, like the other cranial bones, consists of two tables with their intervening diploë.

The anterior surface or outer table of the frontal portion of the bone is convex forwards, and constitutes the forehead. On either side of the mesial plane, and a little below the middle of the bone, is the convexity of the *frontal eminence.* Below this eminence, and separated from it by a shallow groove or depression, is the elevation known as *the supra-*

ciliary ridge. Below this ridge, again, is *the supra-orbital margin,* or orbital arch, a well-defined curved edge of bone which forms the upper boundary of the orbit and the anterior margin of the horizontal plate of the frontal bone. The supra-orbital margin terminates externally in *the external angular process.* Internally, the orbital arch terminates in the *internal angular process,* which articulates with the lachrymal bone and the nasal process of the superior maxilla. At the junction of the inner and middle thirds of the supra-orbital margin is the notch or foramen which transmits the supra-orbital nerve and vessels. Situated in the mesial plane between the two supraciliary ridges, and just above the root of the nose, is the prominence of *the glabella.* The glabella and the supraciliary ridges mark the position of the frontal sinuses which are situated between the two tables of the frontal bone. The smooth area lying immediately above the glabella, and usually forming a depression upon the surface of the bone, is called *the ophryon.* Below the glabella is a narrow, roughened edge of bone sloping downwards and outwards, which gives attachment on either side of the mesial plane to the nasal bone: the line of articulation between these bones constitutes *the nasion,* or fronto-nasal suture.

The inner table of the frontal portion of the bone is concave upon its cerebral surface, and lies in contact with the frontal lobes of the brain covered by the meninges. In the mesial plane it is marked by the sulcus for the superior longitudinal venous sinus, into the lower end of which there sometimes opens a small vein transmitted through the foramen caecum from the nasal mucous membrane.

The horizontal portion of the bone consists of the two orbital plates, which are separated from each other mesially by the wide ethmoidal notch (*incisura ethmoidalis*). In the articulated skull this notch is occupied by the cribriform plate

Plate IX.

Photograph from a frozen section, kindly lent to the author by Prof. Symington. The vertical coronal section is made through the anterior part of the nasal chambers, just in front of the middle turbinated bodies. A well-developed bulla frontalis is seen in the floor of the right frontal sinus. The section passes through the left tear duct, which is seen opening into the inferior meatus.

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of the ethmoid bone. The ethmoidal border of each orbital plate presents a series of small depressions, or *foveæ*, which complete or roof in the air cells of the lateral mass of the ethmoid. Lying in front of these foveæ, on each side, and in series with them, is the aperture of communication with the frontal sinus. The rest of each orbital plate enters into the formation of the roof of the orbit. Its inferior surface is smooth and concave. Anteriorly it is bounded by the well-defined curve of the supra-orbital margin, while posteriorly it articulates with the lesser wing of the sphenoid bone. At its anterior and inner angle, and concealed by the inner third of the supra-orbital margin, is the trochlear depression, sometimes marked by a small bony spine, for the attachment of the pulley of the superior oblique muscle. The superior or cerebral surface of each orbital plate is convex, and is marked by a number of elevations and depressions, upon which rests the orbital surface of the frontal lobe of the brain.

The orbital plate consists of two tables which may be separated from each other. This separation is due either to the backward extension between the tables of the frontal air sinus, or to the outward extension of one or more ethmoid cells; in some cases both these cavities participate in thus hollowing out the orbital roof.

The Frontal Air Sinuses, as already indicated, are two cavities with an intervening bony septum lying immediately above the root of the nose between the two tables of the frontal bone (Plate IX.) These sinuses extend vertically upwards for a varying distance, and in many cases also horizontally backwards between the two tables of the orbital plate. The sinuses are not present at birth. Some difference of opinion has been expressed with regard to the date of their first appearance. This is probably due to the fact that some observers record the period at which the sinus begins to develop, while others note

the age at which the sinus is first recognised as a distinct cavity in the vertical portion of the bone. It is generally held that the frontal sinus commences to develop at the end of the first or at the beginning of the second year of life, as an upward expansion of the ethmoid cell labyrinth. The diverticulum of mucous membrane from the ethmoid air space gradually invades the diploë upon the nasal aspect of the frontal bone. As it extends upwards and outwards, expanding the frontal tables in its growth, it reaches in the sixth or seventh year above the fronto-nasal suture and supra-orbital margin, and can be recognised at that age as a distinct cavity, above the root of the nose. These observations have been described and figured by Steiner.[1] Symington,[2] in his "Anatomy of the Child," records two instances in which fairly well-developed sinuses were found at the age of 9 and 13 years, but, in his observations upon children under 6 years, he did not find a frontal sinus present in the vertical portion of the bone. In two subjects examined by myself, æt. 6 and 7 years respectively, I failed to find any evidence of a sinus above the fronto-nasal and fronto-maxillary sutures; on the other hand, in a subject æt. 12, two well-developed cavities were observed above the root of the nose. It must be borne in mind that deductions drawn from a few observations are open to fallacy, owing to the fact that both sinuses are occasionally absent in the adult. It is difficult to estimate either the rate of growth or the period at which the frontal sinus reaches its maximum development. It is conceivable that the maximum growth is reached in early adult life, when the facial and cranial bones have become fully formed, though some anatomists affirm that the sinuses continue to increase in size up to old age. It has also been stated that the frontal sinuses enlarge during old age. The great

[1] *Arch. f. klin. Chir.*, Berlin, 1871, Bd. xiii.
[2] "The Anatomy of the Child," Edinburgh, 1887.

variations met with in the size of these cavities make it very difficult to obtain positive evidence upon this point, and I have been unable to find any anatomical proof in support of it. The examination of a number of aged, edentulous skulls revealed the presence of frontal cavities varying in size, but not differing in that respect from the sinuses seen in earlier life.

Although the frontal sinus in the adult varies in size, and to a lesser extent also in shape, we are able to recognise, for descriptive purposes, three walls—an anterior, a posterior, and an inferior wall or floor. Further, the two cavities are separated from each other by an intervening bony septum, sometimes described as the internal wall of the sinus.

The Anterior Wall is formed by the convex outer table of the frontal portion of the bone, and lies therefore in the vertical plane. It consists in part of the glabella and supraciliary ridge, and in part of the bone above and below these prominences. The fronto-nasal and fronto-maxillary sutures and the supra-orbital margin constitute its lower limit; owing to the great variations in the size of the sinus, it is impossible to state definitely the upper and outer limits of the anterior wall. The prominence of the supraciliary ridge is not necessarily an indication of the size of the cavity lying behind it. While it is true that large sinuses are found in association with projecting supraciliary ridges, there are many instances where faintly marked ridges and a low forehead are associated with very extensive cavities. Although the aborigines of Australia and the Maoris of New Zealand have usually prominent glabellæ and supraciliary ridges, in many skulls the sinuses are absent, and these prominences consist merely of the thick outer table of the bone.

The anterior wall of the sinus is the thickest of the three, but is subject to very considerable variations, not only in

different skulls, but on the two sides of the same skull. We find also that the whole area of the wall is not of equal thickness throughout. On turning to actual figures, we note that the anterior wall may be less than 1 mm., or as much as 6 to 8 mm., in thickness. In European skulls, however, the higher figures are exceptional. As a rule, it is more common to find that the outer table does not measure more than 3, 4, or at the most 5 mm. A knowledge of this fact may prove of some practical importance. If the surgeon should find, when exploring the region of the sinus, that the bone is of great thickness, and that there is apparently some difficulty in reaching a cavity, he should at once suspect that possibly no sinus exists. In those skulls in which the frontal sinus is absent, the two tables of the frontal bone along with the diploë together form a layer of considerably greater thickness than that formed by the anterior wall of a sinus. It is also well to note here that the dura mater presents a white appearance when seen on removal of the bone, while the lining membrane of the sinus is of a slate-blue colour.

The density of the bone forming the anterior wall of the sinus also varies, in some cases being porous and soft, while in others it is much more compact in structure. These variations in its thickness and density may therefore be due to natural causes, and not result from chronic inflammatory processes in the underlying sinus.

The Posterior Wall of the sinus, which is slightly convex forwards, is formed by the inner table of the frontal portion of the bone. Superiorly it approximates at an acute angle to the anterior wall of the cavity. Inferiorly, however, it becomes continuous with the upper of the two laminæ which constitute the orbital plate of the frontal bone (Plate XXXV.). The posterior wall therefore occupies in part a vertical and in part a horizontal plane, and in the latter situation it forms the roof

PLATE X.

Floor of anterior fossa of skull. The orbital portion of each frontal sinus is opened into from above, and the position of the ostium of each cavity is indicated by an arrow. Both openings are situated posteriorly in this case. Behind the right frontal sinus an ethmoidal cell is seen, the arrow indicating its communication with the nose.

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of the orbital portion of the sinus. Like the anterior wall, it varies in thickness, and not infrequently parts of it are extremely thin, measuring less than half a millimètre. Its posterior surface is in relation to the frontal lobe of the brain, covered with its meninges, and forms part of the anterior wall and floor of the anterior cranial fossa.

The Inferior Wall or *Floor* is formed by the lower of the two bony laminæ which make up the orbital plate of the frontal bone, and corresponds mainly to the upper and inner angle of the roof of the orbit. It is concave upon its inferior or orbital aspect, and convex towards the sinus. The floor is limited anteriorly by the inner third of the supra-orbital margin, while externally and posteriorly its extent varies according to the development of the sinus in these directions. Sometimes the cavity extends along the roof of the orbit as far outwards as the external angular process, while occasionally it is found to reach almost as far back as the optic foramen. Near the mesial plane the floor of the sinus is closely associated with the ethmoid cell labyrinth, with which it is contiguous. It is the thinnest of the three walls.

The Fronto-Nasal Opening, or *Ostium Frontale*, lies in relation to the septum of the sinus, and is situated in the lowest part of the floor. In this respect it differs markedly from the opening of the maxillary sinus, which lies immediately below the roof of that cavity. The dependent position of the frontal opening undoubtedly favours the drainage of inflammatory products from the cavity, and therefore explains the greater readiness with which cases of acute inflammation of the frontal sinus undergo spontaneous cure. If the surgeon takes the septum of the sinus as his guide when exploring the cavity from without, he will, as a rule, easily reach the communication between it and the nose. In some cases, however, a thick layer of bone intervenes between the

septum and the ostium frontale. Plate X. is a view of the floor of each sinus; in this specimen the ostium is situated posteriorly, and the surgeon would probably reach it with some difficulty when operating through the anterior wall of the cavity.

The ostium frontale is always present. This is readily understood when we remember that the sinus is developed by an upward extension from the ethmoid labyrinth. More than one case has been recorded in which the surgeon failed to find any communication between the sinus and the nose. A possible explanation of this apparent anomaly will be given on page 26, when the variations in the configuration of these sinuses are described. The size of the ostium also varies. As the result of measurements which I have made in a large series of macerated skulls, the opening was found to vary from a mere slit, which would not admit the point of a very fine probe, to one measuring 7 × 8 mm. The average diameters were found to be 4 × 3 mm. With the mucous membrane *in situ* the size of the orifice would be somewhat reduced. Blocking of this passage, with the subsequent retention of pus, becomes therefore more easy in one case than in another, so that the symptoms of frontal sinus suppuration must to some extent be influenced by the anatomical condition which is present. The connection between the ostium frontale and the nasal chamber will be more conveniently studied in the chapter dealing with the communications between the different sinuses and the nose.

The Septum.—Between the sinuses there is a thin bony septum. I have never found it incomplete in the normal skull, although this does not agree with the experience of all observers. As a rule, the lamina of bone is very thin, usually less than half a millimètre, though in a certain proportion of cases a greater thickness is found. Communication may be established between the two sinuses, owing to destruction of the

PLATE XI.

FIG. 1.—Female skull, with persistent frontal suture (metopism), and a mesial septum. A pair of small frontal sinuses previously illuminated as indicated by the black line round the cavities.

FIG. 2.—Skull, with persistent frontal suture and mesial septum between the frontal sinuses.

FIG. 3.—Skull, showing an almost symmetrical pair of frontal sinuses, with a mesial septum.

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PLATE XII.

FIG. 1.—A large right frontal sinus with septum oblique to the left.

FIG. 2.—Very large left and smaller right sinus. The septum is broken, but its position is indicated by a ridge passing somewhat obliquely to the right.

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bone in the course of a suppurative process. In the majority of cases the septum occupies the mesial plane. Occasionally, while its upper and lower ends are placed mesially, it may deviate slightly in its middle part to one or other side.

Deviation of the septum to one or other side of the mesial plane is sometimes met with; the obliquity is probably due to the more rapid development of one of the sinuses, in consequence of which the right or left cavity, as the case may be, extends to a varying degree across the middle plane of the forehead. In metopic skulls, where the frontal suture persists, I have always found the septum mesial (Plate XI. Figs. 1 and 2). In these metopic cases, should one sinus develop more rapidly than its fellow, it does not extend across the mesial plane at the expense of its neighbour. On the other hand, when union of the two halves of the frontal bone takes place in early childhood, such extension of one of the sinuses, with consequent deviation of the septum, is anatomically possible. Fig. 3, Plate XI., represents a non-metopic skull with a mesial septum.

Almost any degree of septal obliquity may be met with, varying from a slight deviation of 2 or 3 mm. (Plate XII.), to an extreme case, in which the septum lies so obliquely as to be almost parallel with one supra-orbital margin (Plate XIII.) As a rule, the greater the deviation of the septum, the more pronounced is the asymmetry of the two sinuses. In cases, however, in which the septum is mesial, marked inequality in the size of the cavities may also occur. Whatever degree of septal obliquity may exist, as a rule the lower end of the septum, immediately above the root of the nose, is mesially placed. In only one of the skulls in which I opened the sinuses was an exception to this statement met with, as is illustrated on Plate XIII. Fig. 3. Here the septum, which is oblique, lies altogether to the right, its lower end being 5 mm. and its upper end 15 mm. from the mesial plane. In our study

of the comparative anatomy of the sinuses by means of illumination, several instances of this oblique position of the septum were observed (Chapter VI.).

The question of septal obliquity is not without practical interest. It is possible for the surgeon in an extreme case, when operating through the anterior wall, to open the wrong cavity. One or two cases of this kind have been reported clinically. The anatomical condition which makes this possible is well illustrated in Figs. 1 and 2, Plate XIII. It is one of three instances of a similar kind which I have met with. The septum lies so close to the right supra-orbital margin that the right sinus is reduced to a mere slit. In the event of the occurrence of symptoms and signs pointing to suppuration in the small right sinus, the surgeon would in all probability enter the left cavity on removing the anterior table of bone. A healthy sinus would in this way be opened, and a misconception in diagnosis and an error in treatment established. If the suspected sinus were opened through the orbital roof, as has been carried out by Jansen,[1] a mistake of this kind would not be made.

Variations in the Size of the Cavities.—As we have already indicated in our description of the walls of the sinus, the cavity varies considerably in size; these variations are met with, not only in different skulls, but on the two sides of the same skull. Perfectly symmetrical sinuses are rare, though not infrequently a superficial examination would lead us to infer that the two cavities were of equal size. Careful measurements usually reveal one or more differences. Sometimes the right, sometimes the left sinus, is found to be the larger. In order to obtain the average size of the cavity, a large number of open sinuses were measured: three diameters were taken for this purpose, namely, the vertical height, from the fronto-nasal aperture vertically upwards; the transverse breadth, from the mesial

[1] *Arch. f. Laryngol.*, Berlin, 1893, Bd. i. Heft 2.

PLATE XIII.

FIG. 1.—Skull, showing large left frontal sinus with apparent absence of the right.

FIG. 2.—Same skull, showing large left frontal sinus and a small right sinus with marked obliquity of septum.

FIG. 3.—Asymmetry of frontal sinuses. The septum is oblique and lies altogether to the right of the mesial plane.

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PLATE XIV.

FIG. 1.—Right frontal sinus of very large dimensions; the left sinus has not been opened into.

FIG. 2.—Frontal sinuses of average dimensions.

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septum, horizontally outwards; the antero-posterior depth, from the lower end of the fronto-nasal suture backwards along the orbital roof. It is necessary to state definitely from what anatomical landmarks these measurements are made, as the same points are not taken by all observers. In estimating the height of an unopened sinus, however, it will be found that the lower end of the suture between the nasal process of the superior maxilla and the frontal bone sufficiently indicates the position of the ostium frontale.

The smallest cavity met with measured in height 18 mm. ($\frac{3}{4}$ in.), in breadth 13 mm. ($\frac{1}{2}$ in.), and in depth 5 mm. (Plate XI. Fig. 1).

The largest sinus, on the other hand, bounded internally by a mesial septum, extended as far outwards as the external angular process of the frontal bone. The following figures indicate the diameters of this sinus :—Height, 45 mm. ($1\frac{3}{4}$ in.); breadth, 60 mm. ($2\frac{1}{2}$ in.); depth, 25 mm. (1 in.) (Plate XIV. Fig. 1). A sinus with a greater vertical diameter than the above was, however, met with; in it the cavity extended upwards in the forehead for a distance of $2\frac{1}{2}$ in. In another skull, again, the sinus extended backwards almost as far as the optic foramen.

The following may be regarded as a sinus of average size :— Height, 31·6 mm. ($1\frac{1}{4}$ in.); breadth, 25·8 mm. (1 in.); depth, 18 mm. ($\frac{3}{4}$ in.) (Plate XIV. Fig. 2). A sinus of average size usually extends outwards a short distance beyond the supra-orbital foramen.

On account of the variations in the size of the sinus, it is necessary to indicate to the surgeon the area upon the anterior wall best calculated to insure his entering the cavity in all cases. If the bone be removed immediately above the root of the nose, in the angle between the inner third of the supra-orbital margin and the mesial plane of the forehead, a sinus, if present, will always be opened into.

In considering the question of the depth of the sinus, we must bear in mind that a considerable difference exists, as a rule, between the depth of the vertical portion of the cavity, *i.e.* behind the glabella and the supraciliary ridge, and the depth of the horizontal portion, *i.e.* along the roof of the orbit. Thus we find that behind the glabella the distance between the anterior and posterior walls of the sinus may be 4, 5, 6, 7, or even 8 mm., while in very exceptional cases it measures from 10 to nearly 20 mm. (1–2 cm.). Along the roof of the orbit, on the other hand, the reverse is observed; it is only in the more exceptional cases that the depth of the sinus in this region measures less than 10 mm. (1 cm.), the backward extension of the cavity being much more frequently found to measure 1, 2, and even 3 cm.

The whole question of the superficial extent and of the depth of the frontal sinus has a very important bearing upon the surgical treatment of chronic suppuration. Some operators urge the removal of the whole anterior bony wall of the sinus in the manner first practised by Kuhnt.[1] This is recommended in order to obtain obliteration of the cavity by approximating the superficial soft parts to the posterior wall of the sinus. If the cavity is small and shallow, such a result can be satisfactorily obtained with little or no disfigurement. If the sinus is a large one, however, the depression or sinking in of a considerable area of the skin of the forehead is necessarily followed by deformity. Further, from what has been said above, we must remember that while obliteration of the vertical portion of the sinus in this way is quite feasible, it is very difficult, or indeed impossible, to deal in a like manner with the extension of the sinus along the orbital roof. In considering the question of obliteration of the sinus, we must therefore keep in mind the risk of disfigurement, and the fact that complete occlusion of

[1] "Ueber die Entzündlichen Erkrankungen der Stirnhöhlen," Wiesbaden, 1895.

PLATE XV.

FIG. 1.—The left frontal sinus shows a well-marked recess or diverticulum at its outer angle, due to the presence of an incomplete bony partition.

FIG. 2.—A small recess is seen at the outer angle of the left frontal sinus.

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the whole cavity is frequently impracticable, if we confine ourselves merely to removal of the anterior wall of the sinus. It is necessary, too, for the surgeon to direct special attention to the floor of the sinus while engaged in curetting a diseased mucous membrane. Should he neglect to explore the orbital extension of the cavity, portions of mucous membrane may be overlooked and foci for fresh infection be left. In Jansen's operation,[1] in which the bony floor of the cavity is removed, freer access can be obtained to this region, as well as to the immediately contiguous ethmoid cells.

Inspection of the interior of the frontal sinus reveals the fact that in many cases it is something more than a simple chamber. Imperfect partitions, varying in length, may jut out into the cavity at intervals, and thus produce a number of recesses or bays, which give the sinus an irregular outline. In two specimens examined, there was a well-marked recess close to the mesial plane, due to the formation of a second small and incomplete septum close to the true septum. Usually, however, these recesses are found to exist towards the external angle of the sinus. Fig. 1, Plate XV., illustrates a large diverticulum, the position of which is indicated by the arrow; it passes upwards and outwards above the supra-orbital margin towards the external angular process. The approach to this recess is concealed by a strong bony partition. In all cases of sinus suppuration, when the cavity has been opened, special care should be taken by means of direct inspection, or by probing, to detect such pockets and deal with their contents. It may be necessary to break down the partitions in order to thoroughly remove the mucous membrane. Fig. 2, Plate XV., shows another but smaller recess in the outer angle of the left sinus. Cases are reported in which unsuccessful surgical treatment was due to failure in recognising these recesses. In five

[1] *Loc. cit.*

instances, three of which are here figured (Plate XVI.), I have found the frontal sinus subdivided into an outer and inner cavity by a more or less vertical bony partition. In each case the partition was deficient in its lower part, so that the two compartments communicated with each other, and with the ostium frontale of the same side. In three of the cases this occurred in the left sinus, in the remaining two in the right. In Fig. 1, Plate XVI., the right sinus is absent, and the partition subdividing the left cavity suggests the development of a double sinus upon the left side. In Fig. 2, Plate XVI., a cursory examination might lead us to suppose that we were dealing with a central sinus between a septum composed of two laminæ. This case, however, is merely another illustration of the condition above described; the left sinus consists of two compartments communicating with each other and with the left nasal chamber through a single ostium. In Fig. 3, Plate XVI., the right sinus is subdivided into an inner larger and a smaller outer compartment by a partition somewhat obliquely placed. In two instances I have seen a single sinus occupy the whole frontal area immediately above the root of the nose, and extending from one supra-orbital margin to the other. In one case the cavity was the right, in the other the left frontal sinus, and in each instance the sinus communicated by a single orifice with the nasal chamber of one side. The condition is illustrated on Plate XVII. Fig. 1 is a skull showing the right frontal sinus, the arrow indicating the communication between it and the right nasal chamber. There is no ostium frontale on the left side. In Fig. 2 the whole cavity represents the left frontal sinus, there being no communication with the right nasal chamber. There is no true septum in this case, the partition seen in the figure is merely a buttress passing between the anterior and posterior walls of the sinus; it is incomplete in its lower part, the aperture being indicated by the large arrow

PLATE XVI.

FIG. 1.—There is no right sinus. The left sinus is incompletely divided into an outer and inner compartment, each communicating with the left nasal chamber through a single aperture.

FIG. 2.—The septum lies somewhat to the right of the mesial plane; the left frontal sinus is incompletely subdivided by a vertical partition.

FIG. 3.—The septum between the sinuses is oblique to the left. The larger right sinus is subdivided into an outer and inner portion. Each subdivision communicates with the right nasal chamber through a single aperture.

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PLATE XVII.

FIG. 1.—One large frontal sinus, the right. There is no evidence of a septum and no communication with left nasal chamber.

FIG. 2.—One large left frontal sinus, incompletely subdivided by a partition which is not a true septum. The sinus communicates with the left nasal chamber. There is no communication with the right side of the nose.

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passing from right to left. The smaller arrow is entering the left ostium frontale, through which both compartments communicate with the left nasal chamber. One is justified in regarding this as the correct explanation of the condition, because of the absence of an ostium frontale upon the right side. Had the latter been present in association with a similar aperture on the left side, there would have been good reason for regarding the existing partition as an incomplete true septum intervening between a right and a left sinus. This rare anatomical condition appears to me to offer a possible explanation of those occasional cases in which the ostium frontale has been said to be absent. If suppuration had been present in this case, the surgeon, after entering the cavity upon the left side, would have found a communication with the right side through an apparently perforated septum. Further investigation would have revealed to him the absence of a right ostium frontale, and consequently he would have drawn the conclusion that he had to deal with a right frontal sinus without any nasal communication.

One or both sinuses may be absent. It is necessary to point out that when we refer to the absence of the frontal sinus, we mean that there is no cavity extending into the vertical portion of the frontal bone. This, however, does not exclude the possibility of the existence of a small frontal air space between the two laminæ of the orbital plate. The relative frequency with which this occurs varies somewhat in different races, and for a more detailed account of these variations the reader is referred to the chapter upon the "Comparative Anatomy of the Frontal Sinuses."

The frontal sinus is lined by a very thin muco-periosteal membrane, continuous through the ostium frontale with the lining membrane of the nasal chamber. Its surface is covered by a layer of ciliated epithelium, and it contains a number of mucous glands.

CHAPTER III

THE ETHMOID CELL LABYRINTH (CELLULÆ ETHMOIDALES)

THE ethmoid bone, which plays so important a part in the construction of the two nasal chambers, consists of the mesial vertical plate, the cribriform plate, and two lateral masses. *The vertical plate* forms the upper part of the septum of the nose. *The cribriform plate* passes horizontally from the vertical plate immediately below the crista galli to the upper border of each lateral mass.

Each *lateral mass of the ethmoid bone* contains a number of irregularly shaped air spaces, which constitute the ethmoid cells. Its external lateral surface is a perpendicular plate of bone, named the *os planum* or *lamina papyracea*, which forms the greater part of the inner wall of the orbit. Its internal lateral surface takes part in the formation of the upper part of the outer wall of the nasal chamber, and presents the irregular convoluted appearance which we have already described as the *ethmo-turbinated bones.*

The Ethmoid Air Cells (Cellulæ Ethmoidales) vary in shape, size, and number. They have been grouped by some anatomists into an anterior, middle, and posterior series. Others again have subdivided them into two groups, the anterior and posterior ethmoid cells based on the position of their ostia. The latter anatomical division of the cells provides us, at the same time, with a satisfactory clinical basis. All the cells which communicate with the middle meatus of the nose,

below the line of origin of the middle turbinate bone, are anterior ethmoidal air cells, while those which communicate with the superior meatus above the origin of the middle turbinate are posterior ethmoidal air cells. The relative space occupied by each group in the lateral mass is not constant, nor is there any regularity in the number of cells which each contains. Thus, in one skull, the anterior group of cells may extend backwards, so as to be in close proximity to the sphenoid bone, in another the posterior cells may reach far forwards. Again, a single large air cell, or two or three smaller ones, may represent the posterior group, while as many as seven, eight, or nine anterior ethmoidal cells may sometimes be counted. The plate of bone which intervenes between the two cell groups is diagonally placed between the outer and inner walls of the lateral mass, and does not admit normally of any communication between them. Although we may find in the posterior group one or more cells communicating with the nasal chamber by separate ostia, it is not uncommon to find incomplete septa between the cells, so that a single ostium serves as a common orifice for the whole group. In the anterior ethmoidal cells, on the other hand, there are usually several ostia of communication between the cells and the middle meatus. The Plates which illustrate Chapter V. demonstrate these points.

While the ethmoidal air spaces are bounded externally by the os planum of the ethmoid, and internally by the two ethmo-turbinals, it is otherwise with the remaining four boundaries of the cell labyrinth. Thus superiorly, the ethmoid air cells are completed by the depressions or foveæ on the ethmoidal edge of the orbital plate of the frontal bone. Inferiorly, on the other hand, they are closed in by the ethmoidal edge of the orbital plate of the superior maxilla. Anteriorly and externally the cells are walled in by the lachrymal bone, situated immediately in front of the os planum, and

by the nasal process of the superior maxilla. As these two last-named bones complete the inner wall of the orbit in front, it follows that the ethmoid labyrinth is intimately related to the whole inner boundary of that cavity. Posteriorly, the ethmoid cells are completed by the articulation of the lateral mass with the sphenoidal spongy bone.

The Anterior Ethmoidal Air Cells.—It is still necessary to examine with a little more detail the arrangement of the anterior group of cells. Those air spaces which lie most anteriorly, and which are limited by the lachrymal bone and the nasal process of the superior maxilla, are closely associated with the ostium frontale and the floor of the frontal sinus. Sometimes, indeed, one of these cells develops upwards and forwards towards the cavity of that sinus, forming a distinct prominence upon its floor, to which the term *bulla frontalis* has been applied (Plate IX. p. 15). It is not uncommon also to find one of the anterior ethmoidal cells pushing its way outwards behind or beneath the frontal sinus for a considerable distance between the two tables of the orbital plate of the frontal bone. In such a case the air space in the roof of the orbit is directly continuous with the ethmoid labyrinth. The extension of the anterior ethmoidal air cells into the roof of the orbital cavity beneath the frontal sinus is illustrated in the figures represented upon Plate XVIII. In it the cavity reaches as far back as the optic foramen. This extension of the ethmoid labyrinth deserves more careful attention both from the anatomist and the surgeon. In addition to the special arrangement of cells just referred to, there is situated at the anterior part of the lower border of the lateral mass, and in relation to its nasal aspect, a rounded bony prominence, named by Zuckerkandl the *bulla ethmoidalis*. This structure contains in its interior one or more air spaces, and it will be fully considered in Chapter V. p. 41. Occasion-

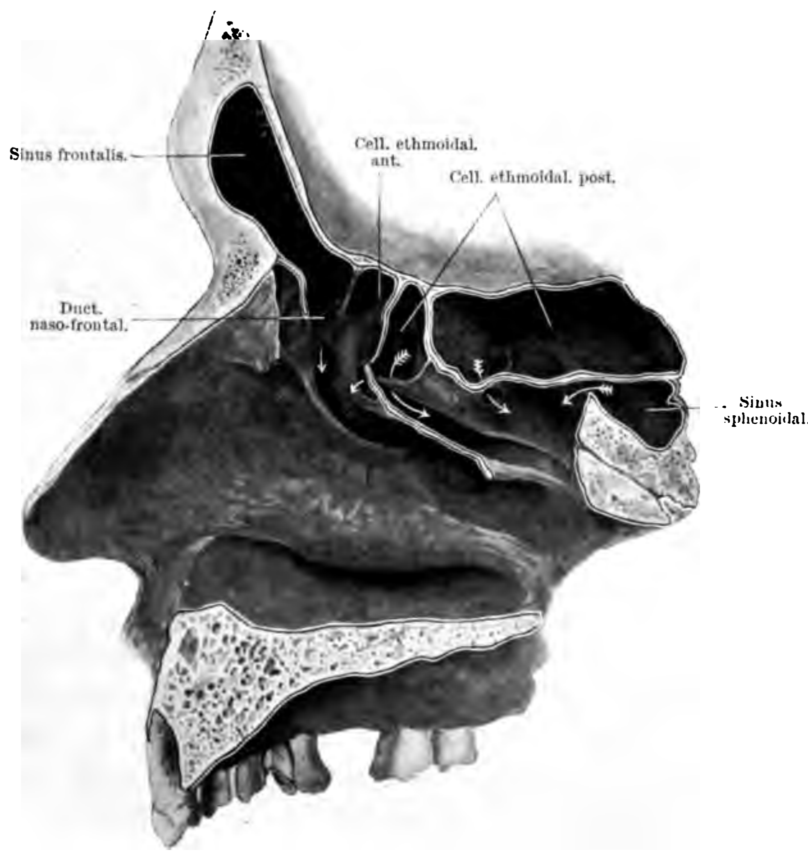
PLATE XVIII.

FIG. 1.—The skull shows a large anterior ethmoidal cell, extending backwards in the roof of the orbit as far as the optic foramen. It lies beneath the floor of the frontal sinus.

FIG. 2.—Cross X marks the floor of the right frontal sinus. A large anterior ethmoidal cell is seen passing into the inner part of roof of the right orbit, beneath the floor of the frontal sinus.

[To face page 30.

PLATE XIX.



Right superior and middle turbinated bodies have been removed. The dissection shows the communication between the frontal sinus and the middle meatus. The infundibulum terminates anteriorly in an ethmoid cell which lies external to the naso-frontal duct, as shown by the arrow. A large posterior ethmoidal cell projects backwards into the sphenoid bone, forming a spheno-ethmoidal cell.

[*To face page* 31.

ally one or more air cells are found in the anterior extremity of the inferior ethmo-turbinated or middle turbinated bone (*concha bullosa* of Zuckerkandl). This cell may be present on one side, but absent on the other. On Plates III. and XXIII. the turbinal air cell is seen communicating with the middle meatus. We are thus able to differentiate among the anterior ethmoidal cells the air spaces which lie in close relation to the ostium and floor of the frontal sinus, the air cells in the ethmoid bulla and middle turbinated bone and sometimes the cell in the roof of the orbit.

The Posterior Ethmoidal Air Cells.—The sphenoidal spongy bone which closes in the ethmoid labyrinth posteriorly does not, as a rule, in the normal condition of the parts, permit of any communication between the ethmoid cells and the sphenoidal sinus. The bone is, however, liable to a certain amount of variation in its position. Thus an ethmoidal air cell may project for a varying distance into the body and lesser wing of the sphenoid bone, so as to encroach upon the region of the sphenoidal sinus, and intervene between the latter cavity and the basis cranii; it may be named the spheno-ethmoidal cell (Plates XIX. and XXIV.). Certain clinical phenomena, indicating the involvement of intracranial structures, and usually associated with suppuration in the sphenoidal sinus, may therefore be ethmoidal in origin.

From the foregoing description it is apparent that the cells of the ethmoid labyrinth are not altogether confined to the lateral mass of the ethmoid bone. Although it is true that the orbital and nasal surfaces of the lateral mass bound the cells externally and internally, the cells encroach upon neighbouring bones and the air cavities which they contain, superiorly and inferiorly, in front and behind. We thus have a number of "border cells." Above and in front in relation both to the orbital plate of the frontal bone and to its sinus are the fronto-

ethmoidal cells, one or more of which may extend for a considerable distance along the roof of the orbit behind or beneath the frontal sinus. Inferiorly are the maxillo-ethmoidal cells, which have already been described and figured in our account of the maxillary antrum (p. 7), while posteriorly we find the spheno-ethmoidal cell, which may also assume considerable proportions. As the bony laminæ which intervene between the various ethmoid border cells and the frontal, maxillary, and sphenoidal sinuses are usually extremely thin, it is possible that caries of the laminæ, followed by perforation, may occur in the course of chronic suppuration, with subsequent infection of a neighbouring cavity. This may afford an anatomical explanation of the frequent occurrence of suppuration in two or more of the accessory sinuses, associated with a similar affection of the ethmoidal cells.

It is further evident that in a number of instances the ethmoidal air cells lie not only in relation to the inner wall of the orbit, but not infrequently also in relation to its roof. As a backward extension of the frontal sinus may also occur between the two tables of the orbital plate, care must be taken not to attach too much diagnostic importance to the different varieties of displacement of the eyeball which may arise in connection with sinus suppuration.

The ethmoid labyrinth is lined by a thin muco-periosteal membrane containing mucous glands, and covered by a layer of ciliated epithelium.

Before concluding this chapter, it is necessary to refer to certain terms which have been employed by different writers in their description of the ethmoid cell labyrinth. Some authors have described the air cells situated close to the floor of the frontal sinus and its ostium as fronto-ethmoidal cells. While one or even more of these air spaces may undoubtedly claim this appellation on anatomical grounds, it must be borne in

mind that all the ethmoidal cells which are completed by the frontal bone are anatomically fronto-ethmoidal cells. This is equally true both of the anterior and posterior division of the labyrinth. Hence the application of the term fronto-ethmoidal to certain air cells in the neighbourhood of the ostium of the frontal sinus can only lead to a confusion of ideas, and is not anatomically correct. Hartmann,[1] again, prefers to describe the anterior ethmoidal cells under the name of the frontal cells. The same objection is applicable here as in the former case. The only air cell to which the term frontal can be applied with anatomical accuracy is the frontal sinus itself. It alone is altogether contained within the frontal bone. It seems wiser, therefore, to adopt a strictly anatomical basis for the nomenclature, so as to avoid confusion. It is thus possible for all who study the subject to recognise that when a certain term is used it implies a definite anatomical relationship. The ethmoidal air cells, whose ostia communicate with the middle meatus through the channel of the infundibulum, are frequently spoken of as the infundibular cells.

[1] "Atlas der Anat. der Stirnhöhle," Wiesbaden, 1900.

CHAPTER IV

THE SPHENOIDAL SINUS (SINUS SPHENOIDALIS)

THE sphenoid bone forms the greater portion of the floor of the middle cranial fossa. As it possesses a close relation to many important intracranial structures, it is necessary to describe briefly the chief anatomical divisions of the bone. It consists of a central part or *body* in which the sphenoidal sinuses are developed. The body of the sphenoid, anteriorly and inferiorly, enters into the construction of the two nasal chambers, articulating mesially with the cribriform and perpendicular plates of the ethmoid bone and with the vomer. Towards its lateral aspect the anterior surface of the body completes the ethmoid cell labyrinth by articulating with the posterior end of the lateral mass. Posteriorly, the body of the sphenoid unites with the basi-occipital. Its superior surface is marked in front by a slight eminence called *the olivary process*, in relation to the optic commissure. Behind this process is a depression in the bone, called the *pituitary fossa*, or *sella turcica*, which lodges the pituitary body. Behind this fossa are *the posterior clinoid processes*, which surmount a prominent ledge of bone named *the dorsum sellæ*, which inclines downwards and backwards and supports the pons Varolii. Projecting horizontally on each side from the anterior part of the upper surface of the body, is *the lesser wing* of the sphenoid, which at its inner end forms *the anterior clinoid process;* it articulates by its anterior border with the orbital plate of the frontal bone.

Lying between the two roots of origin of the lesser wing is the optic foramen which transmits the optic nerve and ophthalmic artery. The under surface of this wing forms the upper boundary of the sphenoidal fissure.

The external or lateral surface of the body of the sphenoid is marked by a shallow groove which runs antero-posteriorly, and indicates the position of the internal carotid artery and the cavernous sinus. The most anterior part of this surface assists in the formation of the inner wall of the orbit, and forms the internal boundary of the sphenoidal fissure. Through this fissure certain important nerves pass from the cranial cavity to the orbit, namely, the third, the fourth, the ophthalmic division of the fifth, and the sixth cranial nerves (Plate XX.). The ophthalmic vein also passes through the sphenoidal fissure in its course from the orbit to the cavernous sinus. From the lower part of each lateral aspect of the body of the bone *the great wing* of the sphenoid projects outwards. Piercing the root of this wing, close to its attachment to the body, is the foramen rotundum, through which passes the superior maxillary division of the fifth cranial nerve. Lying behind, and slightly external to this, is the foramen ovale, which transmits the inferior maxillary division of the same nerve. From the under surface of the adjacent portions of the body and great wing on each side, *the internal* and *external pterygoid plates* project downwards. The Vidian canal, containing the Vidian nerve, pierces the base of the internal pterygoid plate close to its attachment to the under surface of the body.

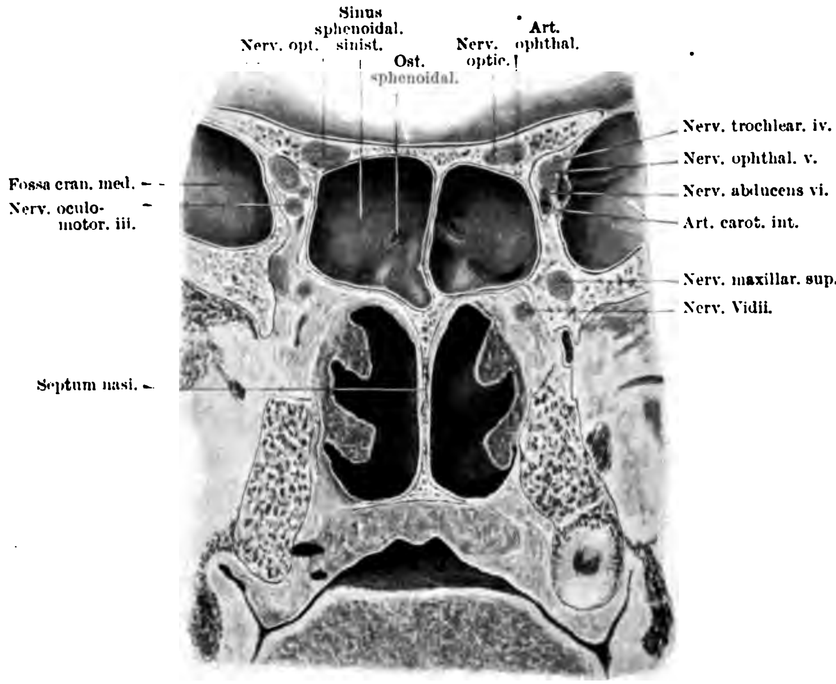
The Sphenoidal Sinuses are two in number, and occupy the anterior portion of the body of the sphenoid bone; a vertical, mesial, bony septum intervenes between the two cavities. The sinuses are not present at birth; Symington[1] states that they begin to be formed in the spongy tissue of the

[1] *Loc. cit.*

bone about the third year, and in a child, æt. 6, he found them fairly well developed. As a rule, two sinuses are present, but one or even both may occasionally be absent. The size of the cavity is subject to a certain amount of variation in different skulls, and inequality in its dimensions on the two sides of the same skull is not infrequently seen. These variations depend upon the amount of absorption which takes place in the cancellous bone in which they are formed; thus the cavities may be limited to the anterior part of the body or may reach as far as and even into the basi-occipital behind, and extend laterally into the bases of the great wings, and superiorly into the lesser wings of the sphenoid. Consequently the larger the size of the cavity the thinner are its walls, and *vice versâ*. This is a point of very great clinical importance in the study of suppuration in the sphenoidal sinus, and demands a careful consideration of the boundaries of the sinus and its relations to neighbouring structures.

Each cavity possesses six walls—a roof, floor, an anterior, posterior, internal, and external boundary. *The roof* of the sinus approaches the horizontal plane, though with an inclination downwards and backwards. It is formed from before backwards by the root of the lesser wing of the sphenoid, the olivary process and the sella turcica; the dorsum sellæ lies behind when the cavity is unusually large; consequently, the following important intracranial structures may lie in relation to the superior wall of the sinus, namely, the olfactory peduncle, the optic commissure, the pituitary body, and the pons Varolii. At the junction of the roof of the sinus with its external lateral wall, the optic nerve and ophthalmic artery pass forwards to the orbit. The plate of bone which forms the roof of the sinus is usually thin. It may measure less than half a millimètre in thickness, or as much as 2, 3, or more millimètres. Defects in the osseous wall have been described by

Plate XX.



Drawing from dissection kindly lent to the author by Prof. Symington. The vertical coronal section passes through the sphenoidal sinuses and the posterior part of the nasal chambers. The various structures which are figured are viewed from behind. The close relation of certain nerves and arteries to the sphenoidal sinuses is well seen.

[To face page 36.

Zuckerkandl and others. Vertical transverse sections through both sinuses demonstrate the fact that the layer of bone between the cavity and the optic nerves may vary in thickness on the two sides (Plate XX.). The extreme thinness of the bone in this situation readily explains the development of partial or complete blindness which may complicate cases of suppuration of the sphenoidal sinus. It has been suggested that in the treatment of chronic suppuration the lining membrane of the cavity should be curetted, and as this operation must be carried out mainly if not entirely by the sense of touch, the necessity of doing so with the greatest care and delicacy cannot be too strongly urged.

The Floor of the sinus forms the most posterior part of the roof of the nasal chamber. The bone is not of the same uniform thickness throughout, and may vary from less than half a millimètre to rather more than 2 mm. When the sinus is large, only a very thin layer of bone may intervene between it and the Vidian nerve.

The Anterior Wall of the sinus occupies mainly the vertical plane, but in its lower part it inclines somewhat backwards and downwards to meet the floor. The sphenoidal spongy bone by which this wall is formed is extremely thin, and measures as a rule less than half a millimètre. It is of considerable surgical importance, mainly from the fact that it contains the nasal opening of the sinus. The anterior surface of the wall may be divided anatomically into an internal part in which lies the ostium of the sinus and an external or lateral area. It is covered by the nasal mucous membrane, and enters into the formation of the roof of the nasal chamber. The external or ethmoidal portion articulates with the posterior end of the lateral mass of the ethmoid bone, and thus completes the ethmoid cell labyrinth in this situation.

The Sphenoidal Opening (*Ostium Sphenoidale*) is situated

in the internal or nasal portion of the anterior wall of the sinus, and communicates with the spheno-ethmoidal recess. (See Plate XX. and the different Plates illustrating Chapter V.) It varies somewhat in its position, but in the majority of cases it is situated in the upper half of the anterior wall; that is to say, it lies nearer the roof than the floor of the sinus, and consequently cannot serve as an efficient drain. The ostium as a rule is of small size, but is subject to some variation; it may vary from an opening measuring $\frac{1}{2} \times 1$ mm. to one measuring 4×4 mm.

The Posterior Wall of the sinus is not of surgical importance. Its distance from the anterior wall of the cavity varies according to the depth of the sinus.

The External Lateral Wall of the sinus, which may be formed of a very thin plate of bone, on its cranial aspect is in relation to the depression for the internal carotid artery and the cavernous sinus. It also forms in its anterior part the inner boundary of the sphenoidal fissure, containing the important nerves already enumerated; anteriorly, too, it takes part in the formation of the inner wall of the orbit (Plate XX.).

The Internal Wall or *Septum* lies vertically between the two cavities, and occupies the mesial plane. It is bony throughout, and usually complete. Deviations from the mesial plane are sometimes met with, and, when marked, give rise to considerable inequality in the size of the two cavities. The septum may occupy a vertical mesial position between the anterior part of the two sinuses, but posteriorly, while still maintaining its vertical position, it may deviate almost at right angles to one or other side, and so unite with the external wall of the sinus. For this reason, one sinus may occupy the whole breadth of the body of the sphenoid bone posteriorly. Occasionally, the septum deviates in a similar

way in its upper half, so that one sinus occupies the whole breadth of the superior segment of the body of the bone.

The size of the sinus varies in different skulls, while inequality on the two sides of the same skull is met with, chiefly when the septum is irregularly developed. As the result of a number of measurements, I have found the average diameters of the sphenoidal sinus to be—vertical height, 20 mm. ($\frac{7}{8}$ in.), antero-posterior depth, 21 mm. ($\frac{7}{8}$ in.), transverse breadth, 18 mm. ($\frac{3}{4}$ in.). The left sinus was larger than the right, probably due to the more frequent deviation of the septum to the right side. These variations in size depend upon such deviations of the septum as have just been indicated; upon defective absorption of the cancellous bone in which the cavities are developed; and, lastly, upon a backward projection of the posterior ethmoidal cells into the sphenoid bone. In those cases in which little bony absorption takes place, the sinuses may be limited to the anterior part of the body of the sphenoid. On the other hand, where there is extensive development, the cavity may reach as far as or extend into the basi-occipital bone behind, while laterally it may occupy the base of the great wing and superiorly the lesser wing of the sphenoid. The clinical symptoms of sphenoidal sinus suppuration, which are due largely to the implication of the various important structures which lie contiguous to the bone which bounds the sinus, depend to a considerable extent upon the size of the cavity, and consequently upon the thickness of its walls.

The sphenoidal sinus is lined by a thin muco-periosteal membrane, which is provided with mucous glands and covered by a layer of ciliated epithelium.

CHAPTER V

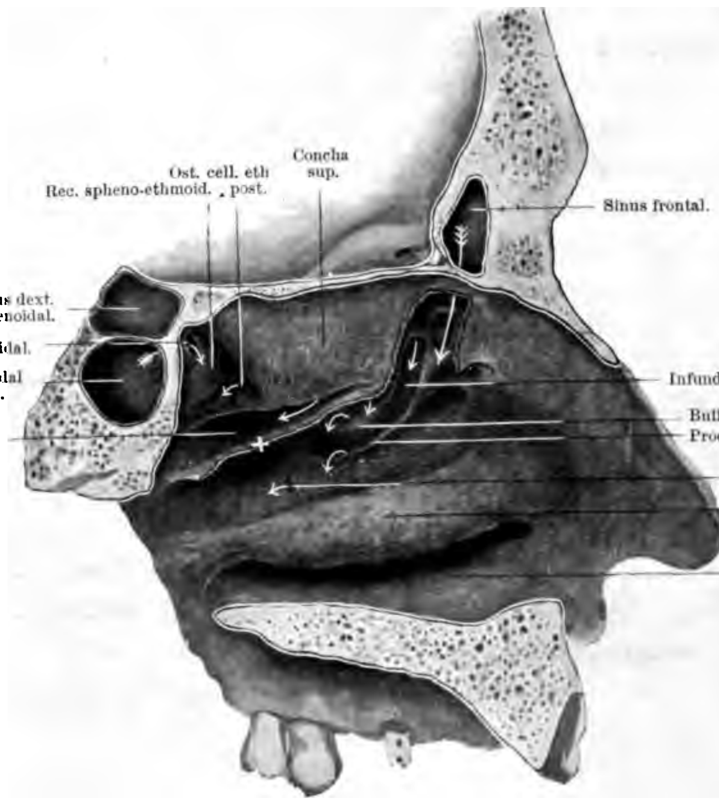
THE OPENINGS OF COMMUNICATION (OSTIA) BETWEEN THE ACCESSORY SINUSES AND THE NASAL CHAMBERS

WE have already indicated in Chapter I. the position and relations of the superior, middle, and inferior meatus, and the spheno-ethmoidal recess upon the outer wall of the nasal chamber. The superior and middle meatus acquire considerable importance, from the fact that through them the various air sinuses just described communicate with the cavity of the nose. The inferior meatus, on the other hand, receives the lachrymo-nasal tear duct, which opens into that channel under cover of the anterior end of the inferior turbinated body (Plate IX. p. 15). In the middle meatus are the ostia communicating with the maxillary antrum, the frontal sinus, and the anterior ethmoidal air cells; that is to say, the air sinuses of the anterior group (p. 4). In the superior meatus, and frequently in a smaller channel, the incisura ethmoidalis superior, lying above it, are situated the ostia of the posterior ethmoidal cells, while in the spheno-ethmoidal recess is the opening of the sphenoidal sinus. These constitute the sinuses of the posterior group.

THE OSTIA OF THE MIDDLE MEATUS

The ostia of the anterior group of sinuses cannot be seen either in the living or in the dead subject without the removal of a considerable portion of the middle turbinated body. In the cadaver, the following dissection can be readily made with a pair of fine-bladed scissors. One blade is passed under the posterior free

Plate XXI.



Dissection of same specimen as that represented on Plate II., showing outer wall of left nasal chamber. The left middle turbinated body has been removed along the line indicated by the X. The position of the ostia of the different sinuses is indicated by the arrows. The infundibulum terminates anteriorly in an ethmoidal cell. The frontal sinus opens directly into the middle meatus in front of the infundibulum. There is a small accessory maxillary ostium lying above the inferior turbinated body.

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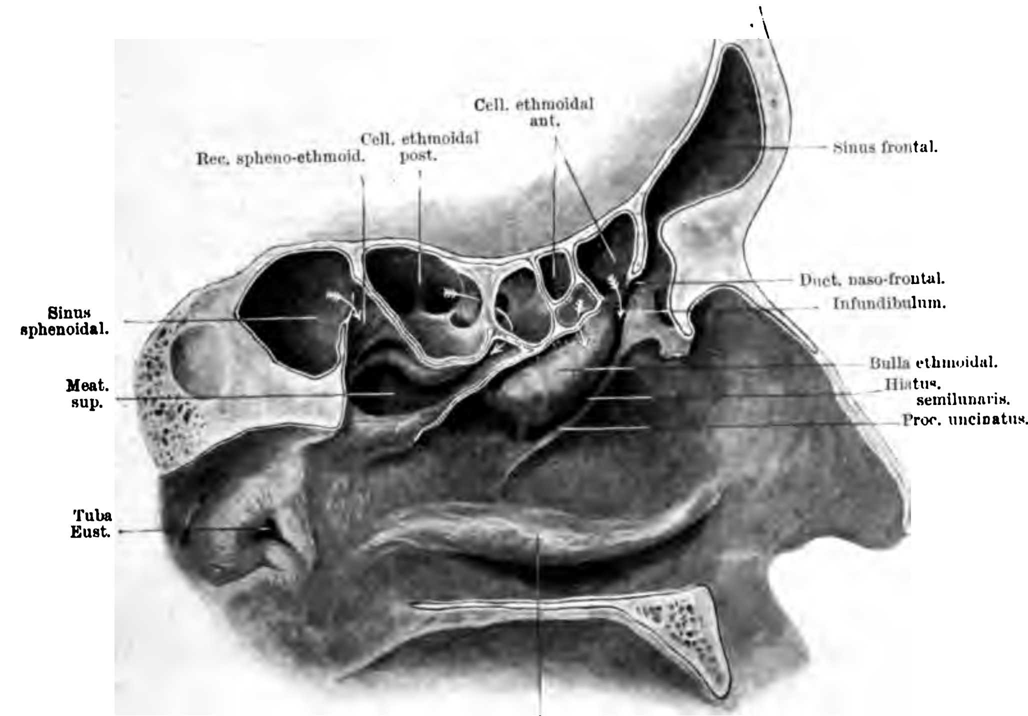
PLATE XXII



Drawing from dissection kindly lent to author by Prof. Symington. Outer wall of left nasal chamber after removal of superior and middle turbinated bodies. The anterior and posterior ethmoidal cells and their communications with the nose are thus exposed. The frontal sinus opens into the infundibulum, that channel being continued directly upwards to the sinus as a narrow and tortuous naso-frontal duct. The bulla ethmoidalis is very large and the hiatus semilunaris is in consequence narrow.

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end of the middle turbinate, and the section is carried obliquely forwards and upwards in the direction of the cribriform plate of the ethmoid. The incision then turns vertically downwards, and divides the middle turbinate close to its attachment to the nasal process of the superior maxilla (Plate XXI.).

Two prominent objects are thus brought into view on the outer wall of the middle meatus, namely, the convex surface of the *bulla ethmoidalis*, and, immediately beneath it, the well-defined curved margin of the uncinate process of the ethmoid (*processus uncinatus*). Between these two structures there is a narrow interval, the semilunar opening or *hiatus semilunaris*. This opening serves as a communication between the middle meatus and a small channel or canal, named *the infundibulum* (Plates XXI. to XXV.).

The Bulla Ethmoidalis—the anatomical position of which has already been indicated in our description of the ethmoid labyrinth—appears as a smooth rounded eminence. Its size varies according to the development of one or more ethmoidal air cells which may be present within it. In one case it may be feebly developed, while in another it assumes very considerable proportions (Plates XXI. and XXII). The size of the bulla greatly influences the width of the hiatus semilunaris. In some cases it approximates so closely to the uncinate process which lies beneath it, that the hiatus is reduced to so narrow a slit that the point of a fine silver probe cannot be passed through it. The air cell in the interior of the bulla communicates directly with the middle meatus by an ostium which is placed close to or upon its superior aspect (Plates XXI. and XXIV.). Consequently, in the erect posture of the head, free drainage of pus from the interior of the bulla cannot take place.

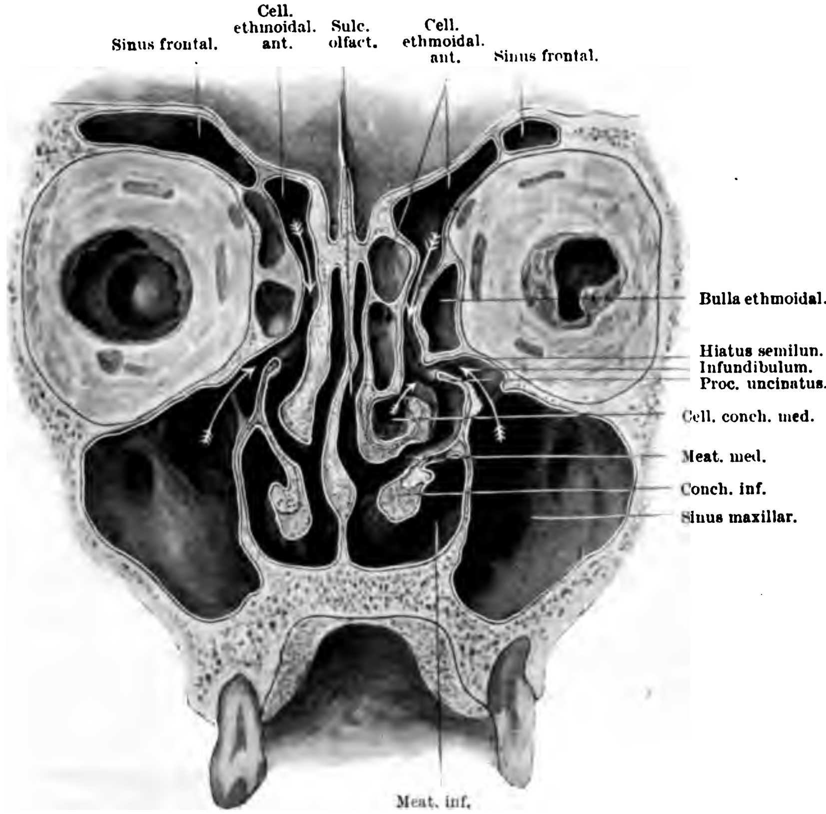
The Processus Uncinatus of the ethmoid is a thin plate of bone in the outer wall of the middle meatus. Covered by mucous membrane, it projects downwards and backwards in

the form of a narrow sickle-shaped shelf from the lower aspect of the anterior end of the lateral mass. Though somewhat obliquely placed, it presents an external and an internal surface, separated from each other by the upper free border of the process, which forms the lower boundary of the hiatus semilunaris (Plates XXI. to XXV.). It frequently terminates posteriorly in two subsidiary processes. The lower of these passes downwards to the upper edge of the inferior turbinated body about its middle, while the other curves upwards behind the posterior end of the bulla (Plate XXII.).

The Hiatus Semilunaris.—The semilunar opening already referred to is bounded superiorly by the convex surface of the ethmoid bulla, and below by the free margin of the uncinate process. It serves as the direct and only communication between the middle meatus of the nose and the infundibulum, along the inner aspect of which it lies. The hiatus averages from 15 to 20 mm. in length, while its width is subject to considerable variation, being mainly influenced, as we have seen, by the development of the ethmoidal bulla.

The Infundibulum is a small gutter-like channel, situated upon the outer wall of the middle meatus. It is bounded above by the inferior surface of the ethmoidal bulla, and below and internally by the external surface of the uncinate process (Plate XXIII.). It is obliquely directed from below upwards and forwards, and corresponds both in its length and in its direction to the uncinate process. The infundibulum is usually closed behind the posterior end of the ethmoid bulla by the upper of the two subsidiary processes in which the uncinate process terminates posteriorly. The superior and anterior end of the infundibulum may terminate in a bony lamina, which passes from the anterior extremity of the uncinate process to the bulla (Plates XXI. and XXV.). In some cases, however, the lamina is not present, and the infundibulum is continued directly

PLATE XXIII.



Drawing from a frozen section, kindly lent to the author by Prof. Symington. It represents a vertical coronal section, viewed from behind, and made through both nasal chambers and maxillary antra on the plane of the antral orifices, through each of which an arrow passes into the infundibulum. The close relation of the frontal, anterior ethmoidal, and maxillary sinuses to the orbit is seen. The communication between the anterior ethmoidal cells and the middle turbinal cell, with the middle meatus on the left side, is also indicated by arrows. The infundibulum is seen in transverse section.

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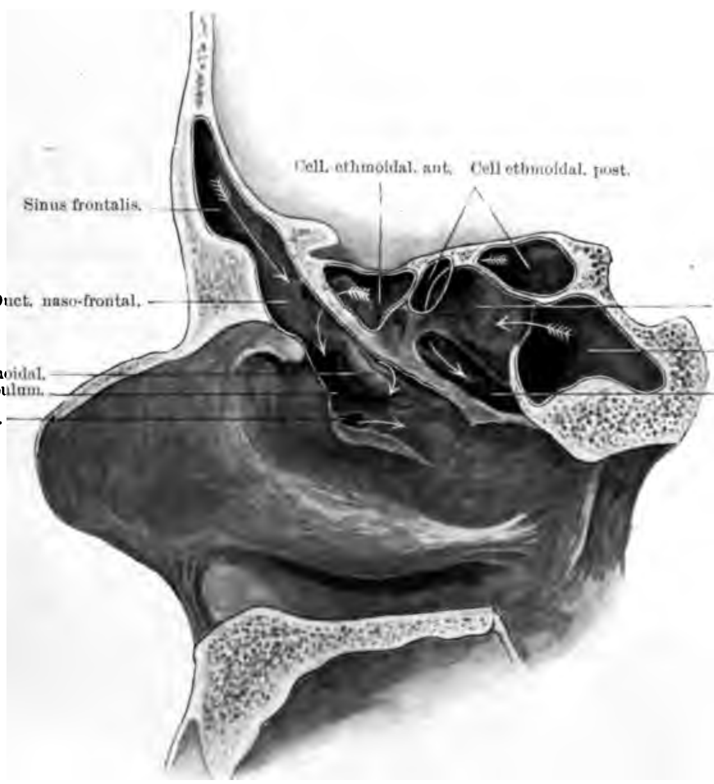
PLATE XXIV.



Dissection, showing outer wall of right nasal chamber. The superior and middle turbinated bodies have been removed. The uncinate process has been turned down, so as to expose the ostium maxillare at the bottom of the infundibulum. The posterior ethmoidal cells are seen extending into the sphenoid bone. There is a wide and very direct communication between the frontal sinus and the ostium maxillare.

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upwards as the naso-frontal duct (Plates XXII. and XXIV.). The outer wall of the infundibulum is formed chiefly by mucous membrane, which intervenes between it and the cavity of the antrum. The floor of the canal is formed by the junction of its outer and inner walls, which meet at an angle. On transverse section, therefore, the infundibular canal presents a somewhat triangular appearance, with the apex downwards. Lying along its whole inner aspect, and forming an interval between its upper and inner boundaries, as has been already indicated, is the hiatus semilunaris (Plate XXIII.).

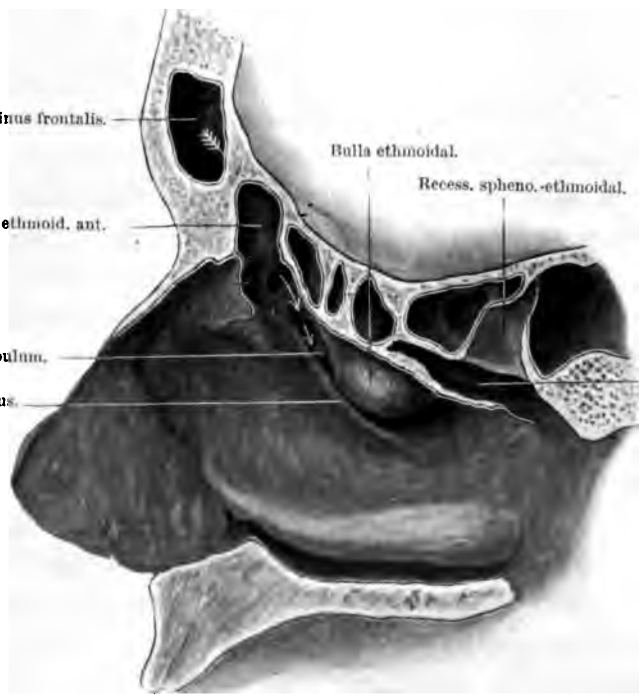
The Ostium Maxillare.—Considerable clinical importance must necessarily be attached to the infundibulum, from the fact that many of the ostia of the anterior group of sinuses open directly into it. After studying the anatomical relations of the different structures which form this channel, it now becomes necessary to examine the position of the various ostia communicating with it. Situated in the most dependent part of the infundibulum, beneath the ethmoidal bulla, and concealed from view by the uncinate process, is *the ostium maxillare.* The position of the ostium is more clearly indicated if the uncinate process be divided and turned downwards, as has been done in the dissection figured on Plate XXIV. The size of the opening varies; it may measure only 2 by 3 mm., or it may have an antero-posterior diameter of 18 mm. When it reaches a considerable size, it may almost entirely replace the outer wall of the infundibulum, and form a long slit-like communication between the antrum and that channel. Behind the maxillary ostium the infundibular canal inclines slightly upwards. The concealed position of the ostium behind the uncinate process, the prominence of the bulla, and the small diameter of the hiatus semilunaris in many cases, are factors which make successful catheterisation of the ostium a difficult and not infrequently an impossible procedure.

Ostium Maxillare Accessorium.—In a varying proportion of cases, the maxillary antrum has a supplementary communication with the middle meatus. I have seen it four times in nine dissections; in one of these cases there were two such accessory openings (Plate VII.). The ostium accessorium varies in size from a small pin-head aperture, measuring 1 mm., to an opening measuring 8 mm. or more in diameter. It is situated in the membranous portion of the outer wall of the middle meatus, and does not communicate with the infundibulum. It is placed a few lines above the upper border of the inferior turbinated body, about the junction of the middle and posterior thirds of that structure, and is plainly visible on the outer nasal wall of the cadaver without any dissection (Plates II. and XXI.). It therefore lies upon a lower plane, somewhat posterior to the infundibular opening of the antrum. Like the latter orifice, it cannot be seen in the living by anterior rhinoscopy, but the upper margin of the inferior turbinated body serves as a guide to its position. Its situation also favours the drainage of pus from the sinus backwards into the naso-pharynx.

Ostia of the Anterior Ethmoidal Cells.—The infundibulum receives the ostia of certain of the anterior ethmoidal cells; these cells are sometimes spoken of as the infundibular cells. They vary in number; their ostia for the most part communicate with the infundibulum upon its outer and posterior aspect. In a number of cases the canal terminates anteriorly in a large ethmoid cell lying beneath the floor of the frontal sinus (Plate XXI.). This cell may form the prominence upon the floor of that sinus which we have already described as the frontal bulla (Plate IX.).

In addition to the anterior ethmoidal cells which open into the infundibulum, we find that there are others which communicate directly with the middle meatus. These cells,

Plate XXV.



Dissection of outer wall of right nasal chamber. The superior and middle turbinated bodies have been removed. An anterior ethmoidal cell extends upwards into the floor of the frontal sinus, lying upon the inner or mesial aspect of the naso-frontal duct, the position of the latter being indicated by the large arrow. The infundibulum terminates anteriorly in an ethmoid cell which lies upon the outer side of the naso-frontal duct, as indicated by the small arrow. The hiatus semilunaris is exceedingly narrow.

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situated above and external to the bulla ethmoidalis, open in conjunction with the ostium of that structure immediately below the line of origin of the middle turbinated bone (Plates XXI. and XXII.). When a middle turbinal cell is present, its ostium also opens independently into the anterior part of the middle meatus (Plate XXIII.).

The Naso-Frontal Duct.—The infundibulum also receives at its upper and anterior extremity the opening of the frontal sinus in nearly half of the cases; in these cases it is continued directly upwards as the naso-frontal duct, which terminates above in the ostium frontale in the floor of the sinus (Plates XXII. and XXIV.). In the remainder of the cases, on the other hand, the naso-frontal duct opens into the middle meatus in front, and independently of the infundibulum (Plate XXI.). According to Lothrop's[1] investigations, the frontal sinus communicates with the infundibulum in rather more than half the cases examined.

The naso-frontal duct requires more detailed study, on account of the importance attached to it in connection with the question of probing the frontal sinus. It varies in length, in its direction, and in the size of its lumen, consequent upon the irregular development of certain of the anterior ethmoidal cells between which it lies. These cells are situated mainly on its external and posterior aspect, less frequently in front of the duct, and only rarely internally to it. Consequently the duct itself occupies the position nearest to the mesial plane of the nose. On Plate XXV. a dissection is figured illustrating the more exceptional condition in which an ethmoid cell lies on the inner or mesial aspect of the naso-frontal duct; this cell extends for a considerable distance upwards, and forms a *cul-de-sac* in the floor of the frontal sinus. In this case the naso-frontal duct is somewhat deviated outwards in its course

[1] *Ann. Surg.*, November and December 1898, January and February 1899.

from the sinus to the middle meatus. Again, the duct may become somewhat tortuous, according as the air cells by which it is partially surrounded are more markedly developed upon one or other aspect of it. Its lumen, too, is influenced by similar causes; thus it may be narrowed and tortuous (Plate XXII.); in other cases it is patent and more or less straight (Plate XXIV.). When the frontal sinus does not communicate with the infundibulum, but opens directly into the middle meatus, the naso-frontal duct is short and straight, and more vertical in position, the sinus being more directly accessible through it (Plate XXI.).

The Ostium Frontale.—The fronto-nasal opening in which the naso-frontal duct terminates in the floor of the sinus, varies in size from a mere slit to an orifice measuring several millimètres (7 × 8 mm.). The average measurements obtained in a number of macerated skulls were 4 × 3 mm. (see p. 19).

A knowledge of the anatomical relations of the different ostia opening into the infundibulum and into the middle meatus is essential for a correct appreciation of certain clinical phenomena. The infundibulum receives on the one hand the maxillary ostium in every instance, the duct from the frontal sinus in a considerable proportion of cases, and the ostia of certain of the anterior ethmoidal cells. On the other hand, it communicates with the middle meatus through the long crescent-shaped opening of the hiatus semilunaris. Secretion from the air sinuses of the anterior group flows, as a rule, into the infundibular canal, and thence, passing through the hiatus semilunaris over the free upper edge of the uncinate process, reaches the middle meatus. When a purulent discharge is secreted by the frontal sinus, in those cases in which the naso-frontal duct is directly continuous with the infundibulum, it tends to flow downwards and backwards, and gravitates towards the maxillary ostium. There can be no doubt that in these cases suppuration in the maxillary antrum may be

secondarily induced by infection from the frontal sinus. The same result may follow the flow of pus from the anterior ethmoidal cells which open directly into the infundibulum. In the erect posture of the head the pus naturally tends to flow towards the lowest point in the infundibulum, and as the prominent shelf formed by the uncinate process serves as an obstacle to its passage into the middle meatus, it gravitates through the ostium maxillare into the antrum. The latter cavity becomes a reservoir for its reception, and it is not until the antrum overflows into the infundibulum, or until the head is bent forwards, that the pus finds its way through the hiatus semilunaris into the middle meatus. We are, I think, justified in concluding that, under certain circumstances, the converse may also take place. It is customary for the patient who is irrigating a diseased maxillary antrum through an alveolar opening, to do so with the head thrown somewhat forward. It is conceivable that pus may be driven from this cavity along the infundibulum to the frontal and ethmoidal cells, especially if syringing is carried out with any degree of force. If the antrum be filled with water in the cadaver, and the head gently tilted forwards, some of the fluid may be seen to enter the frontal sinus.

Probing and Catheterisation of the Frontal Sinus.—This operation is simplified by a knowledge of the anatomical relations of the fronto-nasal region. The variations which have been described sufficiently indicate that the passage of a probe through the anterior naris towards the frontal sinus may meet with some opposition. A successful exploration is most readily obtained in those cases in which the sinus opens directly into the middle meatus anteriorly to the infundibulum. Sometimes the anterior end of the middle turbinated body constitutes an initial difficulty, and in these cases it may be necessary to remove it before attempting the further passage of the instrument. Occasionally a narrow or tortuous duct, or

the small size of the ostium frontale, may prevent the probe reaching the sinus. The chief difficulty, however, is due to the various ethmoidal ostia into which the instrument may tend to pass. We must repeat here that these openings are usually situated upon the outer and posterior walls of the naso-frontal duct, which in the majority of cases lies next to the mesial plane of the nose. The occasional occurrence of a large ethmoid cell upon the inner or mesial aspect of the duct, as figured upon Plate XXV., would undoubtedly prevent successful exploration. If the instrument should enter an ethmoidal air cell, whose blind upper extremity reaches above the fronto-nasal suture, a mistake with regard to its true position would be even more readily made. The distance of the floor of the frontal sinus from the anterior naris has been estimated by Hansberg[1] as 60 mm. (6 cm.), while Cholewa[2] found it to be 70 mm. (7 cm.).

If the surgeon will bear in mind the difficulties that may arise, and endeavour to avoid them, he will in a considerable number of cases successfully catheterise the frontal sinus. After cocainising the nasal mucous membrane, and thoroughly removing every trace of pus, a long fine silver probe is introduced through a Thudichum's nasal speculum, the point of the instrument being guided by the eye with the aid of good illumination. The proximal end of the probe should be bent downwards, so that the operator's hand does not obstruct his line of vision. At the distal end of the instrument, a curve 3 cms. in length is made, having an angle of about 135°. It will be found necessary to slightly vary this curve, however, in different cases, so that the angle cannot be stated with mathematical exactness. In every instance, whether the anterior end of the middle turbinated body has been first removed or not, the point of the instrument is introduced into the anterior part

[1] *Monatsschr. f. Ohrenh.*, Berlin, 1890, Nos. 1 and 2.
[2] *Ibid.*, Berlin, Bd. xxvi. S. 246.

of the middle meatus, and gently insinuated upwards and forwards without any force being employed. The point of the probe should be directed towards the mesial plane, and even kept in contact with the outer surface of the upper portion of the middle turbinated body. A certain amount of gentle manœuvring may be necessary. When a feeling of resistance makes further entrance impossible, the probe should be grasped between the finger and thumb, at the point where the upper lip joins the floor of the nostril, and then gently withdrawn. The portion of the instrument which has been inserted is now laid against the outside of the nose, and the position of its point located externally. If it is then found to reach above the supra-orbital margin, it may be justly assumed that it had previously entered the frontal sinus. In some cases a feeling of doubt may exist whether the instrument has really entered that cavity or one of the anterior ethmoidal air cells. A certain freedom of movement of the point of the probe, and its introduction for a distance of 6 to 7 cm., are facts in favour of its successful insertion into the sinus. A similar procedure may be carried out by means of a frontal cannula. The instrument introduced by Hartmann or Krause may be employed for this purpose. Brown Kelly's pattern is very serviceable, and fulfils all the necessary requirements; as the stem of the cannula is marked in centimètres, the distance of the point of the instrument from the nasal aperture can be readily noted.

THE OSTIA OF THE SUPERIOR MEATUS AND SPHENO-ETHMOIDAL RECESS

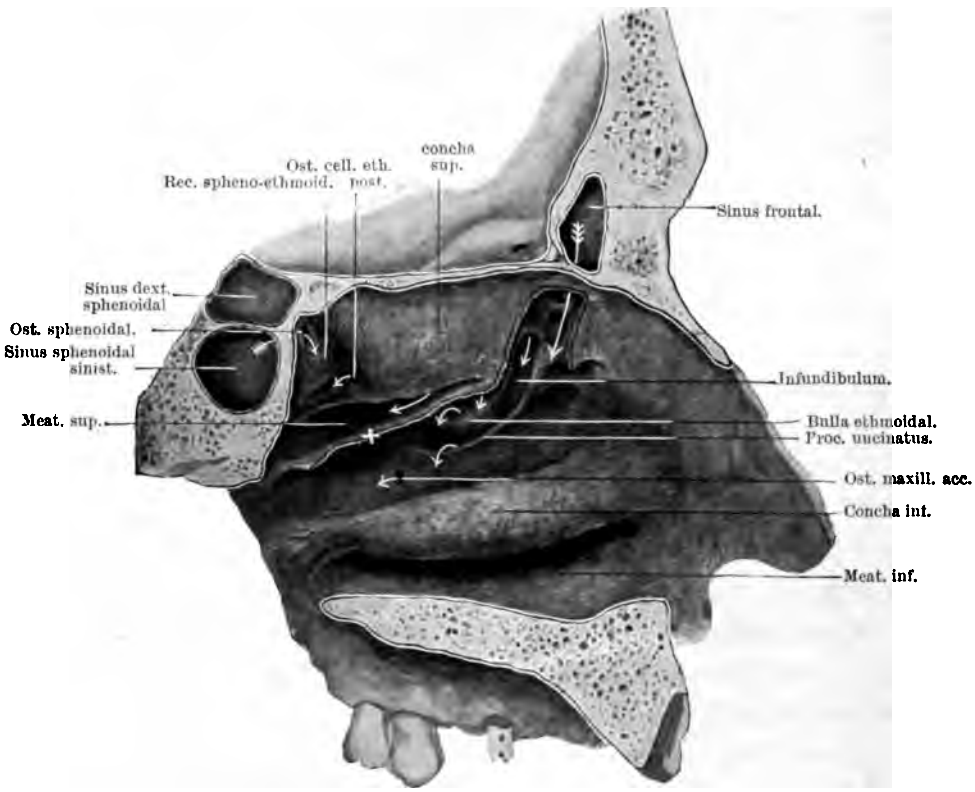
We must now turn our attention to the study of the ostia of communication between the posterior group of sinuses and the nasal chamber. These air spaces communicate with the nose above the middle turbinated body, the posterior ethmoidal

cells opening into the superior meatus, the sphenoidal sinus into the spheno-ethmoidal recess. These ostia, like those belonging to the anterior group, are not visible in the living subject on rhinoscopic examination. In the cadaver, however, no dissection is required to expose them, although their deep-seated position in the superior meatus prevents them from being seen on merely superficial examination.

The Ostia of the Posterior Ethmoidal Cells.—It has been already pointed out, in the description of the ethmoidal labyrinth, that the posterior ethmoidal cells communicate with the nasal chamber through one or more ostia situated in the superior meatus. Not infrequently there is only a single ostium, while as many as three may occur. The most constant of these is situated at the anterior blind extremity of the superior meatus (Plate XXVI.). This ostium is more or less oval in shape, and its diameters vary from 1 × 2 to 3 × 6 mm. The direction of the opening is mainly backwards. A second, or even a third orifice, may be found more posteriorly situated upon the outer wall of the meatus, and directed inwards and slightly backwards. In all these cases the ostia lie somewhat deeply, and are concealed beneath the overhanging inferior margin of the superior turbinated body.

In a varying proportion of cases, perhaps in about one half, the posterior ethmoidal cells have an additional ostium situated in the incisura ethmoidalis superior, the small shallow channel which frequently lies immediately above the superior meatus. More or less circular in shape, the opening is of small size, with a diameter of 1 or 2 mm. (Plate XXVI.). This aperture, which is readily seen on the outer wall of the nasal chamber, communicates with the most posterior and upper of the ethmoidal cells. When a spheno-ethmoidal cell is present, its ostium occupies this situation (Plate XIX.). Occasionally, the sphenoidal sinus is

PLATE XXVI.



Dissection of same specimen as that represented on Plate II., showing outer wall of left nasal chamber. The left middle turbinated body has been removed along the line indicated by the X. The position of the ostia of the different sinuses is indicated by the arrows. The infundibulum terminates anteriorly in an ethmoidal cell. The frontal sinus opens directly into the middle meatus in front of the infundibulum. There is a small accessory maxillary ostium lying above the inferior turbinated body.

[To face page 50.

said to communicate with the incisura ethmoidalis superior. These various ostia are not always situated in the most dependent part of the cells into which they lead.

When suppuration occurs in the posterior ethmoidal cells, the pus finds an exit through the ostia into the superior meatus, and thence on to the upper surface of the posterior half of the middle turbinated body. From this situation the discharge tends to pass in two directions, either backwards and downwards, along the upper surface of the middle turbinated body, through the posterior naris into the naso-pharynx, or by trickling over the inner or mesial surface of that body it finds its way into the olfactory cleft, or the interval between the middle turbinated and the septum nasi. The former course is influenced by the fact that the superior meatus forms a *cul-de-sac* anteriorly, while the upper surface of the middle turbinate is inclined downwards and backwards towards the posterior naris. The frequent changes in the position of the head, necessitated by the patient's daily occupation, must, however, favour the flow of the secretion over the inner surface of the middle turbinate into the more anterior parts of the nasal chamber. The situation of the ethmoidal ostia in the upper and posterior region of the nose renders their catheterisation from the anterior naris both a difficult and an uncertain procedure.

The Ostium of the Sphenoidal Sinus.—The sphenoidal sinus communicates through a single small ostium with the spheno-ethmoidal recess, which is situated upon the superior and posterior aspect of the outer wall of the nasal chamber (Plate XXVI.). Placed in the anterior wall of the sinus, the opening varies somewhat both in its size and in its position. In one of my specimens the diameters of the opening measured only $\frac{1}{2} \times 1$ mm., and would not admit the point of a fine probe; in another, which was the largest met with, the measurements were 4×4 mm. As a rule, the ostium sphen-

oidale lies in the upper half of the wall of the sinus, and is therefore nearer the roof than the floor of the cavity. Sometimes it is found immediately beneath the roof. In other cases, again, it occupies a lower level. In a similar way the relation of the ostium to the septum of the sinus varies, in one case lying in juxtaposition to it, in another being placed more externally (see Plate XX. and Plates showing outer wall of nasal chamber).

It follows, therefore, that the position of the ostium in the spheno-ethmoidal recess is not constant in its relation either to the apex or to the mesial plane of that space. It may be situated in the posterior wall of the recess, close to the mesial plane, or more externally in the angle between its posterior and external lateral boundaries. In the first situation, the opening is directed forwards; in the second, its direction is somewhat inwards and forwards. Although the actual difference between the two positions, when measured in millimètres, is small, the possibility of inspecting or probing the orifice through the anterior naris is readily influenced by slight deviations in its position. The relation of the ostium to the roof of the nasal chamber also varies; in cases in which a spheno-ethmoidal cell intervenes between the sinus and the basis cranii, the sphenoidal ostium may be at some distance from the roof of the nasal cavity. Under normal circumstances, the sphenoidal opening is not visible in the living person by anterior rhinoscopy. This is due to the close proximity of the middle turbinated body to the septum nasi, thus narrowing the olfactory cleft. Removal of the middle turbinated body is necessary before direct inspection is possible, and even then a difficulty may still exist, owing to the lateral position of the opening, as above described, and not infrequently also from the projection of the superior turbinated body. Hajek[1] figures a case in which the sphenoidal opening on

[1] "Pathologie u. Therapie der Entzündlichen Erkrankungen der Nebenhöhlen der Nase," Leipzig u. Wien, 1899.

one side was visible through the speculum, owing to a slight deviation of the septum into the nasal chamber of the opposite side, combined with a marked flattening of the middle turbinated body of the same side. Occasionally, in cases of atrophic rhinitis, where the upper portion of the nasal chamber is roomy, it is possible to see the ostium of the sphenoidal sinus by anterior rhinoscopy.

When pus secreted in the sphenoidal cavity escapes through the ostium, it tends to pass downwards and backwards, and thus reach the vault of the naso-pharynx. It may also flow on to the upper surface of the posterior end of the middle turbinated body, and occupy a position similar to that taken by the secretion escaping from the posterior ethmoidal cells. In this way it may reach the olfactory cleft.

Probing and Catheterisation of the Sphenoidal Sinus.— In order to successfully catheterise the ostium sphenoidale, the surgeon must be acquainted with the relation of that orifice to the anterior naris—that is to say, he must know the distance between the orifice and the nostril, and the direction which the probe must take in order to enter it. When we consider that this operation must be conducted mainly by the sense of touch, a knowledge of these anatomical relations is all the more necessary. The average distance from the point of junction of the floor of the nasal vestibule with the upper lip, to the anterior wall of the sphenoidal sinus, is stated by Grünwald[1] to be 8·2 cm. in males and 7·6 cm. in females. These measurements having been made in a number of living subjects, are consequently of more practical value than those carried out on the cadaver or upon the macerated skull. The observations of Hansberg[2] on the cadaver, and also those made by Hajek,[3] are, however, in close agreement with the above. The direction of

[1] "Die Lehre von den Naseneiterungen," 2nd ed., München, 1896. Translation of the 2nd German edition, by W. Lamb, 1900.

[2] *Loc. cit.* [3] *Loc. cit.*

the probe is of even greater importance. Zuckerkandl has demonstrated the fact that if the probe passed through the olfactory cleft, so that it crosses the middle of the inferior margin of the middle turbinated body, be continued upwards and backwards, it will impinge upon the anterior wall of the sphenoidal sinus. In other words, the probe should form, with the plane of the floor of the nasal chamber, an angle of about 45°, somewhat less than half a right angle. If this angle approaches more nearly to a right angle, the probe will come in contact with the cribriform plate in front of the sinus. If, on the other hand, a smaller angle is formed, the probe will tend to pass through the posterior naris into the naso-pharynx. As the position of the ostium in the vertical plane varies, it follows that this angle cannot be definitely laid down. While a knowledge of these facts is undoubtedly necessary for the success of this procedure, there must frequently remain an element of doubt in the operator's mind as to whether the probe or catheter is actually in the ostium sphenoidale. Owing to the lateral position of the opening in some cases, the point of the probe may with advantage be bent slightly outwards. Grünwald[1] draws attention to the fact that if the point of the instrument merely enters the spheno-ethmoidal recess, it can be moved freely in a downward direction; on the other hand, if it enters the sphenoidal opening, such a movement is not possible, the probe being supported by the lower margin of the ostium. Grünwald's sphenoidal sinus cannula is bent at its proximal extremity, so that the hand may not interfere with the line of vision, but the stem of the instrument is straight. In the majority of the cases in which sphenoidal sinus suppuration is suspected, greater satisfaction will probably be obtained by first removing the middle turbinated body, so as to endeavour to bring the sphenoidal ostium under direct ocular inspection.

[1] *Loc. cit.*

CHAPTER VI

THE COMPARATIVE ANATOMY OF THE FRONTAL SINUSES IN HUMAN CRANIA

WHILE it is doubtless true that at the present day the anatomy of the frontal air sinuses is of interest mainly to the surgeon, the fact remains that for many years the attention of the anatomist has been turned to a consideration of these cavities. In association with the other large air spaces connected with the nose, much speculation has from time to time been aroused as to the probable function of the sinuses. It is interesting to read in this connection the views of the anatomist, Alexander Monro, primus, and it will not be out of place to quote here his somewhat quaint description of these cavities, published early in the eighteenth century.

"In a natural and sound state these cavities are of considerable advantage, for, the organ of smelling being thus enlarged, the effluvia of odorous bodies more difficultly escape it: and their impressions, being more numerous, are therefore stronger and affect the organ more. That odorous particles may be applied to the membrane of the sinuses, is evident from the pain felt in this part of the forehead when the effluvia of volatile spirits or of strong aromatics are drawn up into the nose by a quick inspiration. These and the other cavities which open into the nose increase the sound of our voice, and render it more melodious by serving as so many vaults to resound the notes. Hence people labouring under a coryza, or

stoppage of the nose from any other cause, when they are by the vulgar, though falsely, said to speak through their nose, have such a disagreeable, harsh voice. The liquor separated in the membrane of these sinuses drills down upon the membrane of the nose to keep it moist."

While recognising the confusion of ideas in the mind of the author, and his evident failure to discriminate between the olfactory sense and that of common sensation, we are inclined to agree with him in regard to the resonating function of these chambers. In all probability they serve as subsidiary resonators for the voice. The absence of olfactory nerve filaments in the lining membrane of the sinuses excludes the possibility of their participating with the Schneiderian membrane in the function of smell, while the small size of their ostia renders it extremely improbable that they can take any part in the warming or moistening of the air in connection with nasal respiration.

Owen, in his description of the comparative anatomy of the vertebrates, draws attention to the fact that the frontal sinuses are seldom developed in the skulls of the aboriginal Australians. Further proof of this fact has been furnished by the examination of a number of Australian and Maori crania, which have been included in this investigation. It has been suggested that the somewhat flat character of the voice in these native tribes is due to the absence or feeble development of the nasal air sinuses.

Sir George Humphry,[1] in his description of the human skeleton, considers that, in addition to the part which they play in modulating the tone of the voice, they assist in lightening the facial bones. "Their development is contemporaneous with the downward growth of the facial bones. In proportion as this goes on, and the vertical distance between the alveoli and the cranium is increased, so are the sinuses excavated to lessen the gradually preponderating weight in this part of the

[1] "The Human Skeleton."

skull, and to maintain a near approach of equilibrium between the regions in front of and behind the occipital condyles."

In the early years of the last century, considerable interest of a different kind was manifested in the frontal air sinuses. The doctrine of phrenology, so fully expounded by Gall and Spurzheim on the Continent, and by Combe in Scotland, was at that time combated by Sir William Hamilton.[1] Phrenology taught that there was a correspondence between the volume of certain parts of the brain and the intensity of certain qualities of mind and character, and that these areas of the brain were moulded within the cranial vault so as to influence the development of the contour of the skull. Hamilton correctly argued that, owing to the presence of the air cavities, and the consequent divergence from parallelism of the two tables of the frontal bone, there could be no relation between the surface of the brain and the external surface of the calvaria. Consequently, in the region of the forehead at any rate, the groundwork of phrenology based on the contour of the cranium was weakened, if not destroyed.

Not only in man, but also in many of the lower animals, certain organs were placed by the phrenologists in the region of the glabella ossis frontis. Thus, in the dog, Gall localised immediately above the root of the nose the organ of Aptness to Learn and Retain Things. The degree of prominence of this area of the forehead varied, according to that author, in proportion to the capacity which that animal showed of being taught. Fig. 1 upon Plate XXVII. demonstrates the existence of a large sinus in the glabellar region of the dog, and a consequent separation of the two tables of the frontal bone. The same authority reasoned in a similar way with regard to the elephant. No better demonstration, however, could be offered of the uselessness of comparing the external configuration of

[1] *Med. Times and Gaz.*, London, May, June, August, 1845.

the skull with the development of the brain surface, than by observing the enormous and widely diffused spaces in the skull of that animal (Plate XXVII. Fig. 2). In the frontal region of the horse, where Combe has placed the organ of Benevolence or Good-nature, a roomy sinus is also interposed between the two tables of the frontal bone (Plate XXVI. Fig. 3).

The study of the frontal area of the male gorilla presents certain features of interest. The thick and massive supra-orbital ridges consist for the most part of solid bone, but in the slightly depressed area of the skull lying between these ridges and the elevation of the forehead, two well-developed sinuses may be present (Plate XXVII. Fig. 4).

No attempt to investigate the comparative anatomy of the frontal sinuses in man upon an extensive scale has apparently hitherto been made. An examination carried out for the purpose of making accurate measurements of the size of these cavities necessitates the removal of a considerable area of bone, and consequently results in some degree of disfigurement of the skull. With the introduction of electric transillumination by Voltolini, and its application to the frontal sinuses by Vohsen, this difficulty in the way of an extended research has been removed. A very satisfactory method of accurately delineating these cavities and their intervening septum upon the frontal surface of the skull, has thus been obtained. After carrying out a number of observations, both upon the macerated skull and upon the cadaver, I have satisfied myself of the scientific accuracy of this mode of observation, which was first pointed out by Kuhnt. This method of investigation has consequently been applied to the following research into the racial characteristics of the frontal sinuses.

As the whole subject of transillumination is dealt with in considerable detail in Chapter VII., it is not necessary to describe here the method of illuminating the frontal cavities

Plate XXVII.

Fig. 1.—Skull of dog.

Fig. 2.—Skull of elephant.

Fig. 3.—Skull of horse.

Fig. 4.—Skull of gorilla.

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(see p. 120). Suffice it to say, that each skull was examined in a dark room, the sinuses illuminated, and a permanent record of their outline obtained by mapping out the illuminated areas with a pencil, and subsequently measuring them. In many skulls no illuminated area was obtained, in some cases due to the absence of these cavities, in other cases owing to the thickness or density of the bony walls. In other skulls, again, while it was evident that a sinus was present, the illumination was imperfect, and consequently no attempt was made to measure the size of the cavity. Only those sinuses were measured which were evidently completely mapped out, and their intervening septum delineated. It must be clearly stated, at the outset, that the absence of illumination does not necessarily imply the absence of a sinus. Such an assumption would lead to considerable error. In those cases in which the illumination proved to be negative, the ostium frontale was carefully probed, and frequently a small hole was drilled through the inner third of the orbital roof before any conclusions were drawn. Even when it was found impossible to measure the sinuses, the skulls were nevertheless of service in estimating the percentage of frontal sinuses present in the race under consideration.

By the illumination method it is only possible to measure the vertical and transverse diameters of the frontal cavities. A number of observations made upon open sinuses shows that, as a rule, the lower end of the suture between the frontal bone and nasal process of the superior maxilla indicates on the outer surface of the skull the most dependent part of the sinus. Consequently the vertical measurements were made from this point to the highest limit indicated by the pencil line. The breadth of the cavity was measured horizontally outwards from the line denoting the septum. The results have been noted in millimètres. Adult crania alone were examined, so as to ex-

clude the possibility of any fallacy arising from the examination of imperfectly developed sinuses. In order to compare the sinuses in the two sexes, the male skulls were differentiated from the females. The former are larger and heavier, their glabellæ and supraciliary ridges attain a greater development, and the bony projections for the attachment of muscles are more prominent. The skulls examined belong to the collection in the Anatomical Museum of the University of Edinburgh.

The investigation, however, has not been confined merely to ascertaining the dimensions of the sinuses in different races, the frequency of their occurrence, and their sexual characteristics. An attempt has also been made to ascertain whether these cavities show any distinctive features in the various skull types, and whether any relation exists between the height and breadth of the sinus and the height and breadth of the skull. For this purpose a series of cranial measurements were made, and the Cephalic, Vertical, and Height-Breadth index of each skull was ascertained. A brief explanation of the nomenclature employed to indicate the different types of skull is necessary. The term Cephalic index is used to express the proportion between the maximum length and breadth of the skull. Three main groups are recognised: the Dolichocephalic type, which includes those skulls whose length is proportionately greater than their breadth; the Brachycephalic, in which the length and breadth more closely approximate to each other; and the Mesaticephalic, which occupy an intermediate position. The Vertical or Altitudinal index indicates the proportion which exists between the maximum length and the height measured from the basi-occipital to the bregma; in this too, there are three subdivisions: the Tapeinocephalic skulls, in which there is a low vertical index, the height of the skull being considerably less than the length; at the other end of the scale are the Akrocephalic skulls, with a relatively greater

vertical diameter; while the Metriocephalic skulls form an intermediate group. Lastly, in considering the Height-Breadth index of the skulls, the following subdivision was made:—The first group comprised those in which the breadth of the skull exceeded its height, where the Height-Breadth index was therefore a low one; the second included those in which the height of the skull exceeded the breadth; while in the intermediate group these two diameters were equal.

The total number of skulls examined for the purpose of investigating the above points was 578. The series was made up in the following way:—

Europeans	240
Asiatics	70
Australians	69
Tasmanians	8
Maoris (New Zealand)	35
African Tribes	41
Egyptians	20
Esquimaux	19
North American Indians	29
South American Indians	12
Sandwich Islanders	35
	578

We shall commence by a study of the European crania, in the first place reviewing the main features which characterise the frontal sinuses in the individual races, and then drawing certain general conclusions from the facts thus ascertained.

A. EUROPEAN CRANIA (240)

Scottish	124
English	16
Irish	20
French	37
Carry forward	197

Brought forward . .	197
German	13
Russian and Poles	8
Swiss	7
Greeks	6
Turks	3
Austrians	2
Danish	1
Flemish	1
Italian	1
Spanish	1
	240

1. Scottish Crania

One hundred and twenty-four skulls gathered from different localities in Scotland were examined. Of these, 89 were male crania and 30 were female, while 5 were not classified, as the sex characteristics were not sufficiently well marked. The Mesaticephalic type of skull predominated, as almost half of the number belonged to that group. Of the remainder a considerable proportion were Dolichocephalic; while a small number, 13·4 per cent., were Brachycephalic. The mean Cephalic index of the series was therefore Mesaticephalic. Both the Vertical and Height-Breadth indices were low, the majority of the skulls being Tapeinocephalic, while in nearly all of them the breadth of the skull exceeded the height.

The Frontal Sinuses.—Amongst the Scottish crania, as in the other races, it was found impossible to measure the diameters of all the sinuses that were present, owing to imperfect illumination in a number of the skulls. The cavities were fairly well developed throughout the series. The largest pair of sinuses in one skull gave the following measurements :—

	Right.	Left.
Height	47 mm.	51 mm.
Breadth	42 „	53 „

While the smallest pair, on the other hand, measured—

	Right.	Left.
Height	20 mm.	16 mm.
Breadth	18 „	13 „

The average size of both cavities was as follows:—Mean Height, 29·8 mm.; Mean Breadth, 26·6 mm. In both diameters, therefore, these sinuses may be regarded as being of average dimensions. The right sinus was slightly larger than the left. It will not be out of place to state that calculations based upon an examination of several hundred frontal sinuses represent a standard sinus as measuring 31·6 mm. in Height and 25·8 mm. in Breadth.

Sex characteristics.—In the male skulls the frontal sinuses were both higher and broader than they were in the female.

Presence and absence.—One of the most interesting points inquired into was the relative frequency of absence of one or both sinuses. The following facts were ascertained upon this point. Both sinuses were present in 95 skulls, *i.e.* in 76 per cent. Both sinuses were absent in 15 skulls, or in 12 per cent. The right sinus was absent in 6 skulls, or in 4·8 per cent. The left sinus was absent in 8 skulls, or in 6·4 per cent. That is to say, one or both sinuses were absent in 29 skulls, or in 23·3 per cent. An examination of the male and female skulls gave the following results:—Both sinuses were absent in 6 male skulls and in 9 female skulls, while one sinus was absent in 11 male and in 3 female skulls. There were thus 17 male and 12 female crania showing absence of development of one or both of these cavities. Although the figures show a slight preponderance in favour of the male skulls, the sinuses were more frequently absent in the female skulls, as the number of the male skulls examined exceeded the female skulls in the proportion of three to one.

2. English Crania

This series contained 16 skulls, of which 14 were male and two female. The majority of the skulls, like the Scottish, belonged to the Mesaticephali, hence the mean Cephalic index was Mesaticephalic. All of them were Tapeinocephalic, and had a low Height-Breadth index, the breadth of the skull, with one exception, exceeding the height.

The Frontal Sinuses.—These cavities showed rather less variation in size than amongst the Scottish crania. The largest pair in the series measured—

	Right.	Left.
Height	44 mm.	42 mm.
Breadth	51 ,,	43 ,,

The smallest pair in the English crania was—

	Right.	Left.
Height	27 mm.	20 mm.
Breadth	28 ,,	29 ,,

Consequently the average measurements of the sinuses were somewhat larger than in the Scottish crania. Thus the Mean Height was 32·8 mm., and the Mean Breadth 31·2 mm. The average transverse diameter of the sinuses was therefore considerably greater than that which observation has shown to be of average dimensions. The mean diameters of the right and left cavities showed very little difference between each other, nevertheless the right sinus was slightly larger than the left, owing to its having a somewhat greater vertical measurement.

Sex characteristics.—Of the two female crania in the series, it was only possible to measure the frontal sinuses in one of them, so that no comparison could be made between the sinuses in the two sexes.

Presence and absence.—We find that in the 16 skulls

under consideration both sinuses were present in 14, or in 87·1 per cent.; both sinuses were absent in one, or in 6·2 per cent.; while the left sinus was also absent in one skull. Thus, in 12·5 per cent. of the English crania, one or both of the frontal cavities were not present. Both of these skulls were male.

3. Irish Crania

This series contained 20 skulls, of which 15 belonged to the male sex and 5 to the female. One-half of the skulls were classified as Dolichocephalic, 8 as Mesaticephalic, and 2 as Brachycephalic. The mean cephalic index, however, was Mesaticephalic, but it approached more nearly to the Dolichocephalic type than in the Scottish and English races. Further, the skulls were Tapeinocephalic, and possessed a low Height-Breadth index, the height of the skull in no case being in excess of the breadth.

The Frontal Sinuses.—These cavities were well developed, the majority of them, indeed, being above the average. The largest pair measured—

	Right.	Left.
Height	44 mm.	42 mm.
Breadth	40 „	35 „

while the smallest in the series was—

	Right.	Left.
Height	28 mm.	28 mm.
Breadth	30 „	21 „

The average height and breadth measurements were, Mean Height, 36·1 mm.; Mean Breadth, 30 mm. In both diameters, therefore, these sinuses exceeded the average, while they were higher than the mean of the sinuses in the Scottish and English crania. In further distinction to the two previous races, we

find that the left sinus was on an average both higher and broader than the right.

Sex characteristics.—In the male skulls the sinuses were undoubtedly larger than in the female. If we tabulate the average measurements of the cavities in the two sexes, and compare them with the mean of the series, the relative differences in size are at once apparent—

	Male Sinuses.	Female Sinuses.	Sinuses of Series.
Mean Height .	38 mm.	32·1 mm.	36·1 mm.
Mean Breadth .	32·3 „	25·1 „	30 „

Both sinuses were present in each of the 20 skulls forming the series.

General Consideration of the Frontal Sinuses in the British and Irish Crania

The total number of skulls examined was 160. In 106 of these, transillumination permitted of accurate measurement of the height and breadth of the frontal sinuses. In the accompanying table the mean size of these cavities can be seen at a glance—

Race.	Mean Height.	Mean Breadth.
Scottish	29·8 mm.	26·6 mm.
English	32·8 „	31·2 „
Irish	36·1 „	30 „
Great Britain and Ireland	32·9 „	29·2 „

In the Scottish and English crania, the right sinus was slightly larger than the left, while in the Irish the opposite condition existed. Amongst the Irish the sinuses were larger, the increase in size being mainly due to the fact that the cavities were higher than in the other two races.

In the male skulls the sinuses were larger than in the female.

In a small proportion of cases one or both frontal sinuses were absent. Thus out of 160 crania, 31, or 19·3 per cent., had one or both of these cavities absent. In 16 of the skulls both sinuses were absent; in 6, the right sinus; and in 9, the left. Thus the left sinus was rather more frequently absent. Studying this point in relation to sex, we find that the non-development of the sinuses occurred in 19 male and in 12 female crania. Owing to the fact that the male crania exceeded the female almost in the proportion of three to one, it follows that the sinuses were more frequently absent in the female than in the male skulls.

It is not our intention at this stage of the investigation to attempt to draw any comparison between the sinuses in the different skull types met with in the British and Irish crania. Although the skulls in these races are mainly Mesaticephalic, both Dolichocephalic and Brachycephalic types are present, so that it would be possible to compare the sinuses in these different groups. It will be better, however, to consider this question later, when we are dealing with unmixed races, in which the crania are of one type. It will also be possible at a later stage to compare the height and breadth of the sinuses in the British crania, in which the breadth of the skull exceeds the height, with the same diameters in other races in which the skull height exceeds the breadth.

4. French Crania

Of the 37 skulls included in this series, 31 were male and 5 female; in one, the sex could not be determined, owing to the absence of distinctive markings. The majority of the skulls were Brachycephalic, although a considerable proportion had a lower cephalic index, and belonged to the Mesaticephalic. In three the Dolichocephalic type was found. The mean

cephalic index of the series was therefore Brachycephalic. The mean vertical index was Tapeinocephalic, and, with one exception, the breadth of the skull exceeded the height.

The Frontal Sinuses.—These cavities were, on the whole, well developed. A greater disparity existed between their height and breadth measurements than was found in the English and Scottish sinuses, owing to their having a somewhat greater vertical diameter.

The largest pair of cavities in one skull measured—

	Right.	Left.
Height	50 mm.	46 mm.
Breadth	46 „	43 „

These figures not only represent the largest pair, but also the maximum measurements obtained in any sinus in the series. The smallest pair, on the other hand, was—

	Right.	Left.
Height	27 mm.	28 mm.
Breadth	19 „	23 „

These figures, however, do not represent the smallest diameters met with. Thus, in one instance, the height of the sinus was only 20 mm., while the transverse measurement of the two narrowest cavities was 15 and 11 mm. respectively. The average dimensions of the sinuses in the series were consequently reduced by the presence of such small cavities, and the following figures express the two diameters thus:—Mean Height, 33·6 mm.; Mean Breadth, 27 mm. The right sinus was somewhat larger than the left, while the average dimensions were greater in the male than in the female crania.

Presence and absence.—We find that in the 37 skulls examined, both sinuses were present in 32, or in 86·5 per cent. Both cavities were absent in one skull, or in 2·7 per cent.; while either the right or left sinus was each absent in two skulls, or in 5·4 per cent. Therefore, in five of the skulls, *i.e.* in 13·5 per

cent., one or both sinuses were absent. Four of these skulls were males, and only one was female.

5. German Crania

In a small series containing 13 crania, the following interesting points may be noted :—11 of the skulls were male and two were female. They were Brachycephalic and Tapeinocephalic, and possessed a low Height-Breadth index, the breadth of the skull exceeding the height in every instance. In these points they resembled the French crania.

The Frontal Sinuses.—In the German crania the frontal sinuses were well developed, and both in the vertical and transverse diameters the mean exceeded that obtained in the British and French sinuses.

The largest pair in one skull measured—

	Right.	Left.
Height	43 mm.	43 mm.
Breadth	55 „	60 „

The breadth of each cavity, therefore, exceeded the height, a relation which occurs in individual sinuses, and is to be regarded as exceptional. In two other skulls, however, a slightly greater vertical diameter was obtained, the figures in them reading 45 mm. The smallest pair of sinuses measured—

	Right.	Left.
Height	29 mm.	29 mm.
Breadth	16 „	20 „

While the Mean Height of the series was found to be 35·3 mm., the Mean Breadth measured 33·9 mm. In this group the left sinus proved to be somewhat larger than the right.

It is interesting to again note the influence of sex upon the average Height and Breadth of the sinuses. It is true that

there were only two female skulls in the series, but if these be excluded from the total sinus measurements, we find that the Mean Height and Breadth of the sinuses in the male crania not only exceeded considerably the diameters of the sinuses in the female crania, but also the mean of the series. The following table will illustrate these points :—

	Male Sinuses.	Female Sinuses.	Sinuses of Series.
Mean Height . .	36·8 mm.	29·7 mm.	35·3 mm.
Mean Breadth . .	36·2 „	24·5 „	33·9 „

Presence and absence.—In none of the skulls were both frontal sinuses absent; in two of them, however, there was only one sinus; in one case the right, in the other the left being present. In the series of 13 skulls, therefore, there were two or 15 per cent., in which one of the cavities was absent. Both of these were male crania.

6. Swiss Crania

This small group of seven crania was made up of six male skulls and one female. With one exception, all of them were Brachycephalic. The vertical index was somewhat higher than in the French and German crania, the mean measurements placing the series of skulls amongst the Metriocephali. In all the breadth of the skull exceeded the height, thus giving a low Height-Breadth index.

The Frontal Sinuses were fairly well developed, the largest pair measuring—

	Right.	Left.
Height	43 mm.	44 mm.
Breadth	43 „	41 „

while the smallest was—

	Right.	Left.
Height	37 mm.	35 mm.
Breadth	26 „	19 „

The figures show the mean height and breadth of the sinuses to be as follows:—Mean Height, 35 mm.; Mean Breadth, 29·1 mm. In the single female skull, only one of the sinuses could be measured. This was a small one. The right sinus was somewhat larger than the left. Both sinuses were present in each of the seven skulls.

7. Russian and Polish Crania

In this series, consisting of eight skulls, we find that five were regarded as being Russian and the remaining three Polish. They will, however, be considered together. Six of them presented the characteristics of the male skull, while the remaining two were female. Although four belonged to the Mesaticephalic and four to the Brachycephalic, the mean cephalic index placed them in the Brachycephalic subdivision. Like the Swiss, their mean vertical index was Metriocephalic. In all the skulls the Breadth exceeded the Height.

The Frontal Sinuses were on an average smaller than those previously met with in the European races. This diminution in size was evident in both diameters of the cavities, but was mainly brought about by the diminished transverse diameter. The largest pair in the series measured—

	Right.	Left.
Height	28 mm.	40 mm.
Breadth	21 „	40 „

while the smallest was—

	Right.	Left.
Height	30 mm.	26 mm.
Breadth	25 „	16 „

The Mean Height of the series was found to be 30 mm., while the Mean Breadth was 22·7. The latter was therefore somewhat

below the average. The left sinus was somewhat larger than the right, and in the male skulls the cavities were greater than in the female.

Presence and absence.—Of the eight skulls forming the series, both sinuses were absent in one skull, *i.e.* in 12·5 per cent. This was a male skull. In one female skull there was no left sinus. Therefore, in two skulls, or in 25 per cent., one or both sinuses were absent.

8. Grecian Crania

The six skulls in this series were males. They were equally divided between the Mesaticephali and the Brachycephali, but their mean measurements placed them high up in the Mesaticephalic subdivision. They were also Metriocephalic. In all, with one exception, the breadth of the skull exceeded the height.

The Frontal Sinuses.—The following measurements indicate the vertical and transverse diameters of the frontal sinuses. The largest pair measured—

	Right.	Left.
Height	33 mm.	30 mm.
Breadth	29 ,,	36 ,,

while the smallest pair measured—

	Right.	Left.
Height	28 mm.	30 mm.
Breadth	19 ,,	30 ,,

The Mean Height and Breadth of the sinuses in the series measured—Height, 31·8 mm.; Breadth, 27·7 mm.

In one skull the left sinus was absent, thus giving a percentage of 16·6 in which there was absence of development.

9. Turkish Crania

The three skulls in this series were male. Two were Dolichocephalic and one Brachycephalic, making the mean cephalic index Mesaticephalic: they were also Metriocephalic. In two of the skulls the breadth exceeded the height, while in the third the opposite condition existed.

The Frontal Sinuses.—Both sinuses were present in all the skulls, the Mean Height of the cavities being 34·5 mm., and the Mean Breadth 29·7 mm.

10. Austrian Crania

These were two in number, both belonging to the male sex. They were Mesaticephalic and Tapeinocephalic, and the breadth of the skulls was greater than the height.

The Frontal Sinuses.—Both sinuses were present in each skull, their Mean Height being 35·5 mm., and the Mean Breadth 24 mm.

11. Italian Cranium

Male; Brachycephalic; Akrocephalic.
Skull Breadth greater than Height.
Mean Height of both sinuses, 34·5 mm.
Mean Breadth of both sinuses, 29 mm.

12. Spanish Cranium

Male; Dolichocephalic; Metriocephalic.
Skull Height greater than Breadth.
Mean Height of both sinuses, 36·5 mm.
Mean Breadth of both sinuses, 37·5 mm.

13. Danish Cranium

Male; Dolichocephalic; Tapeinocephalic.
Skull Breadth greater than Height.
Mean Height of both sinuses, 34 mm.
Mean Breadth of both sinuses, 26 mm.

14. Flemish Cranium

Male; Brachycephalic; Metriocephalic.
Skull Breadth greater than Height.
Mean Height of both sinuses, 29 mm.
Mean Breadth of both sinuses, 23 mm.

General Consideration of the Frontal Sinuses in the European Crania.

It is now necessary to examine the European crania collectively, and to endeavour to formulate certain general conclusions from the various facts which we have already recorded. It is impossible to draw any general deductions from the small number of Austrian, Italian, Spanish, Danish, and Flemish crania, so that the facts which we have above tabulated relating to these skulls must stand by themselves. Altogether, 240 European crania were examined. These are made up of 160 skulls from Great Britain and Ireland, while the remaining 80 are from such continental countries in Europe as Germany, Switzerland, Russia, Poland, Greece, Turkey, Austria, etc.

Sex.—In considering the question of sex, we find that the male crania largely predominate, being 187 in number, while only 47 are female. In the remaining six it was impossible to differentiate the sex characteristics.

Type of Skull.—With regard to the type of skull met with in the European races, it must be borne in mind that the

cephalic index, as stated in each race, merely expresses the mean type in the various skulls examined, and must not be taken to imply that all the skulls had the same index. Consequently we must be careful not to regard the figures which express the average height and breadth of the sinuses in each series as signifying the diameters of these cavities in the particular type of skull which is mentioned.

We have, however, calculated separately the Mean Height and Breadth of the sinuses in the Dolichocephalic, Mesaticephalic, and Brachycephalic European skulls, and have been unable to find any definite type of sinus in the different skull groups. Thus, amongst the Scottish crania all three types of skull are represented, and the average measurements of the frontal sinuses in these subdivisions are as follows :—

	Dolichocephali.	Mesaticephali.	Brachycephali.
Mean Height . . .	34·2 mm.	26·5 mm.	31·1 mm.
Mean Breadth . .	28·4 „	24·3 „	29·6 „

Again, amongst the French crania we find—

	Dolichocephali.	Mesaticephali.	Brachycephali.
Mean Height . .	40·7 mm. (2 skulls)	34·1 mm.	32·1 mm.
Mean Breadth .	31·5 „ „	28·7 „	26 „

A study of these figures shows that, at any rate in these different types in Europeans, the sinuses follow no definite plan as regards their dimensions.

Attention has frequently been drawn to the fact that in nearly all the European crania the breadth of the skull exceeds the height. We shall subsequently deal with a type of skull in which the opposite condition is present, and we shall then tabulate and compare the height and breadth measurements of the frontal sinuses in these two different skull forms (see p. 88).

The Frontal Sinuses in the European crania are, as a rule, well developed, and do not present much variation in the

different races. It is true that comparatively small cavities and relatively large ones are sometimes met with, but the average measurements amongst the different races do not show a great range of variation. Thus, in the Scottish crania, in which the lowest mean height of sinus is obtained, the average vertical measurement is 29·8 mm., while in the Irish crania, the mean height of the sinuses is 36·1 mm. The mean breadth of the cavities varies from 22·7 mm. in the Russian crania to 33·9 in the German skulls. The sinuses in the German crania, with their mean height only one mm. less than that of the Irish, are the largest amongst the Europeans examined (Plate XXVIII.). The following table gives the different measurements in the various races :—

TABLE I., *showing Mean Measurements of Frontal Sinuses in European Crania.*

Race.	Mean Height of Sinuses.	Mean Breadth of Sinuses.
Crania of Great Britain . .	31·8 mm.	29·7 mm.
„ Ireland . . .	36·1 „	30 „
„ France . . .	33 6 „	27 „
„ Germany . . .	35·3 „	33·9 „
„ Switzerland . .	35 „	29·1 „
„ Russia and Poland .	30 „	22·7 „
„ Greece . . .	31·8 „	27·7 „
„ Turkey . . .	34·5 „	29·7 „

The average measurements in the European crania, therefore, are—Mean Height, 33·5 mm.; Mean Breadth, 28·7 mm. In both diameters they are somewhat larger than the standard which we have adopted as constituting a sinus of average dimensions.

PLATE XXVIII.

FIG. 1.—British cranium.

FIG. 2.—Irish cranium.

FIG. 3.—French cranium.

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In four of the European races—namely, the Scottish, English, French, and Swiss—the mean of the right sinus somewhat exceeded that of the left; while in the Irish, Germans, Russians, and Greeks, the opposite condition existed, the left sinus being the larger. In the crania of the other races, there were not sufficient data from which to draw conclusions upon this point.

In every instance, where a comparison could be made between the sinuses in the male and female crania, the mean height and breadth of the cavities in the former exceeded those in the latter. The average size of the sinuses in each series of skulls was therefore reduced by the presence of the female crania.

The Position of the Septum which intervenes between the two sinuses was ascertained and noted in a large number of instances. Out of 175 European crania in which it was possible to define its position, it was found to be mesial in 138, or in 78 per cent., while in the remaining 37 there was some degree of obliquity. This varied in amount, but in only three cases did it equal or exceed one cm. The most marked example of this kind occurred in a German skull, where the upper end of the septum lay rather more than 1½ cms. to the left of the mesial plane. In 20 cases the deviation of the septum lay to the left, in 17 to the right of the mesial plane.

Presence and absence. — The question of the relative frequency of absence of one or both frontal sinuses in the skull of man is one of considerable importance, and, as already indicated, a careful inquiry was made into this point. In the 240 European crania which were examined, 41, or 17 per cent., had one or both sinuses absent. Of these, 18 skulls, or 7·5 per cent., had no sinuses; while 23, or 9·5 per cent., had only one sinus, in 9 instances the right frontal sinus, and in 14 the left, being absent. Of the 41 skulls in which one or both frontal cavities were absent, 30, or three-fourths, occurred amongst the Scottish and English crania. As

the actual number of skulls examined in these two races exceeded the remainder in practically the same proportion, we are justified in concluding that, among the other European races, the frontal sinuses are absent in a more or less corresponding proportion. The following table will illustrate these points :—

TABLE II., *showing Absence of Frontal Sinuses in European Crania.*

Race.	One or both Sinuses absent in
140 Scotttish and English crania .	31 skulls, or 22·1 per cent.
20 Irish crania . . .	None absent.
37 French crania . . .	5 skulls, or 13·5 per cent.
13 German crania . . .	2 skulls, or 15·3 ,,
7 Swiss crania . . .	None absent.
8 Russian crania . . .	2 skulls, or 25 per cent.
6 Grecian crania . . .	1 skull, or 16·6 ,,
3 Turkish crania . . .	None absent.
In 240 European crania . .	41 skulls, or 17 per cent.

Of the 41 skulls in which one or both sinuses were absent, 27 were male, and 14, or half the number, were female. Throughout the series the male crania exceeded the female in the ratio of 4 to 1, consequently the sinuses were proportionately more often absent in the female than in the male skull.

B. ASIATICS (70 Crania)

Burmese, ...	44
Chinese, ...	12
Siamese, ...	5
Chins and Lushais, ...	9
	70

1. BURMESE CRANIA

This interesting series of skulls, 44 in number, was entirely composed of male crania. The majority were of the Brachy-

PLATE XXIX.

FIG. 1.—Burmese cranium.

FIG. 2.—Burmese cranium.

FIG. 3.—Chinese cranium.

FIG. 4.—Chinese cranium.

FIG. 5.—Siamese cranium.

[*To face page* 79.

cephalic type, although no fewer than 7 of them were grouped among the Dolichocephali; the mean cephalic index of the series however was Brachycephalic. These skulls also gave a high vertical index, and were classed among the Akrocephali. Here, as in the European crania, the breadth of the skull exceeded the height in 34 instances. This difference, however, must be noted, namely, that these two diameters more closely approximated to each other than in the skulls previously studied.

The Frontal Sinuses in the Burmese crania were undoubtedly well developed. Taking 31 mm. to express the standard height of the frontal cavities, we find that out of 65 sinuses which were measured in the series, no fewer than 57 exceeded this average vertical diameter; in as many as 42 the vertical diameter was more than 35 mm. The largest pair of sinuses that we have ever met with in any skull occurred in this race. It is figured on Plate XXIX. Fig. 2. Its measurements were as follows:—

	Right.	Left.
Height	46 mm.	59 mm.
Breadth	43 „	60 „

The smallest pair in the series was—

	Right.	Left.
Height	25 mm.	35 mm.
Breadth	15 „	25 „

The mean height and breadth of the series were—Mean Height, 36·5 mm.; Mean Breadth, 29·2 mm. (Plate XXIX. Fig. 1). In their mean vertical diameter, therefore, they somewhat exceeded the mean obtained in the European series. The Burmese skulls, however, are all male crania, and the mean of the series is consequently not influenced by the inclusion of a number of female crania with smaller frontal sinuses. If we compare the average vertical diameters of the male Burmese

sinuses with the same diameter in the male Irish, German, and Swiss crania, we find that the sinuses in the latter races are higher than in the male Burmese. The right sinus in the series was on an average larger than the left.

Presence and absence.—Out of the 44 skulls, 8, or 22·2 per cent., had one or both sinuses absent. Thus three of the skulls had no sinuses, while in four the right, and in one the left, sinus was absent.

2. Chinese Crania

In this series of 12, eleven of the skulls were male, while one was a female skull. Like the Burmese, the same cranial features presented themselves, the average measurements showing them to be Brachycephalic, Akrocephalic, and with the skull breadth slightly in excess of the height.

The Frontal Sinuses.—Notwithstanding the similarity in the skull types of the two races, a distinct contrast was found to exist between the frontal sinuses in the two groups, the cavities in the Chinese being undoubtedly smaller. It is true that in one instance an exception was met with; in this skull we find the largest pair of sinuses in the series. This is figured upon Plate XXIX. Fig. 4.

	Right.	Left.
Height	43 mm.	54 mm.
Breadth	25 „	47 „

The smallest pair, on the other hand, measured—

	Right.	Left.
Height	17 mm.	19 mm.
Breadth	12 „	18 „

while the average measurements in the series were:—Mean Height, 26·2 mm.; Mean Breadth, 20·5 mm. (Plate XXIX. Fig. 3). The frontal sinuses not only presented a marked con-

trast to those of the Burmese, thus illustrating the difficulty of establishing a relation between the skull type and the size of the sinuses, but were also below the standard measurements which we have already laid down. If the single large pair of sinuses be excluded from the measurements of the series, the average is still further reduced, and it is then found that in the remainder the Mean Height is 23·7 mm., while the Mean Breadth measures 18 mm. The average measurements of the right and left sinuses were the same.

Sex. — It was interesting to observe that the height and breadth of the two sinuses in the single female skull somewhat exceeded the mean in the male crania. It would, however, be unreasonable to draw any conclusions on such a point from the measurements in a single skull.

Presence and absence.—Out of the series of 12 skulls there were two, or 16·6 per cent., in which the right sinus was absent. In no instance were both the sinuses absent.

3. Siamese Crania

Of the five skulls in the series, all were male; further, they were Brachycephalic and Akrocephalic, and in all of them the breadth of the skull somewhat exceeded the height.

The Frontal Sinuses.—Owing to the thickness of the osseous walls of the sinuses, it was found impossible to illuminate the cavities in all the crania, consequently only a small number of measurements were obtainable, and in only one of the skulls was it possible to measure both sinuses. The largest sinus measured 32 mm. in height and 26 mm. in breadth, while the smallest was 26 mm. high and 17 mm. broad. The mean diameters of this small series were—Mean Height, 29·2 mm.; Mean Breadth, 22 mm. (Plate XXIX. Fig. 5). In one of the 5 skulls, *i.e.* 20 per cent., both sinuses were absent.

4. Chin and Lushai Crania

These skulls, nine in number, were obtained from the hill country lying on the north-east frontier of India and to the north-west of Burma. Six of them belonged to the Chin hillmen and three to the Lushai, but both groups may be considered together.

Of the skulls, seven were male and two were female. In contradistinction to the skulls belonging to the natives of Burma and Siam, the crania now under consideration were mainly of the Dolichocephalic type, and presented a lower vertical index, only two of them, indeed, being Akrocephalic. In the majority the breadth of the skull exceeded the height.

The Frontal Sinuses were fairly well developed. The largest pair met with measured—

	Right.	Left.
Height	40 mm.	40 mm.
Breadth	43 „	41 „

while the smallest, on the other hand, measured—

	Right.	Left.
Height	22 mm.	35 mm.
Breadth	13 „	23 „

The mean of the series gave the following measurements :—Mean Height, 32·9 mm. ; Mean Breadth, 26·1 mm. The right sinus was somewhat larger than the left. In one of the skulls the left sinus was absent.

General Consideration of the Frontal Sinuses in the Burmese, Chinese, Siamese, Chin, and Lushai Skulls.

The majority of the Burmese, Chinese, and Siamese crania which we have just considered, present a type of skull which differs from that described in the European races. They are

mainly Brachycephalic, and possess a high vertical index, being Akrocephalic, and although, as in Europeans, the breadth of the skull usually exceeds the height, these two diameters are more nearly equal than they are in the latter races, with perhaps the exception of the Greeks and Turks. As already indicated, there is amongst the Chins and Lushais a skull type differing from that of the Burmese, notwithstanding their close geographical relation. In these two tribes the type of skull is Dolichocephalic, while their mean vertical index shows them to be Metriocephalic.

The Frontal Sinuses.—As a type of skull different from that already studied now presents itself, it is important to study the development of the frontal sinuses in these crania, and to compare these cavities with those already described. The following table will show at a glance the Mean Height and Breadth of the frontal sinuses in the Brachycephalic skulls :—

TABLE III., *showing Mean Measurements of Frontal Sinuses in Asiatic Crania.*

Race.	Mean Height of Sinuses.	Mean Breadth of Sinuses.
Burmese	36·5 mm.	29·2 mm.
Chinese	26·2 „	20·5 „
Siamese	29·2 „	22 „

If these figures be compared with Table I. upon page 76, it will be found that, with the exception of the Burmese, the sinuses are not so high in the Akrocephalic skulls as they are in the Tapeinocephalic skulls of Great Britain, France, or Germany. Further, the sinuses in the Tapeinocephalic Irish skulls are the same height as those in the Akrocephalic skulls of Burma. The breadth of the sinuses, also, is less than in the majority of the European races. In both the Chinese and Siamese, indeed, the sinuses are below the average (Plate

XXIX.). Although the height and breadth of the skulls in these Asiatic races more closely approximate to each other than they do in the majority of the European skulls, there is no corresponding relation between the same two diameters of the sinuses. The height of the sinus still exceeds its breadth in a very similar ratio to what is found in the European crania. In the Asiatics the average size of the right frontal sinus was slightly greater than that of the left. Owing to the absence of female skulls, it was impossible to make any comparison between the sinuses of the two sexes.

Presence and absence.—Of the 70 Asiatic skulls which were examined, 58, or 82·8 per cent., had both frontal sinuses present, while 12 skulls, or 17·1 per cent., had one or both sinuses absent. In four skulls both the sinuses were absent, and in six skulls the right, and in two skulls the left, sinus was not present. All these were male crania. Although the percentage of skulls in which one or both sinuses were absent is the same as amongst the European crania, *i.e.* 17 per cent., the number of Asiatic skulls examined was considerably fewer, indeed four times as few as the European crania. This fact would indicate a more frequent absence of these cavities in the Asiatic races.

C. THE AUSTRALIAN CRANIA

The skulls belonging to the aboriginal Australians, which form the basis of this part of the investigation, were procured from different parts of the Australian continent; 69 in number, they were made up as follows:—

19	skulls from	New South Wales.
14	„	Victoria.
11	„	Queensland.
6	„	South Australia.
4	„	Western Australia.
15	„	Locality not mentioned.

Of these, 49 were male and 20 were female skulls. With only five exceptions, all the skulls in this series were of the Dolichocephalic type. Although in a considerable number the vertical index was a fairly high one, the majority of the skulls were Tapeinocephalic, consequently this was the mean vertical index. We find, however, in estimating the Height-Breadth index, a different type of skull from that previously met with. While it is true that in a small proportion the breadth of the skull exceeded the height, and in a still smaller number the breadth and height were equal, in no fewer than 45 of the crania the height exceeded the breadth. The Height-Breadth index was therefore a high one. Consequently, we have now to consider a type of skull not previously described in our comparative investigation.

The Frontal Sinuses.—It is unfortunate that in so many of the Australian crania the bony walls enclosing the frontal sinuses were too thick to permit of the electric rays traversing the cavities. In a considerable proportion of the skulls, therefore, the frontal sinuses could not be mapped out, and no measurements could be made. In all, 31 sinuses contained in 20 skulls were measured, and the results noted here are based upon the measurements obtained in that number. The sinuses were fairly well developed. Thus the largest pair met with in one skull measured—

	Right.	Left.
Height	49 mm.	50 mm.
Breadth	42 „	43 „

while the smallest pair was—

	Right.	Left.
Height	18 mm.	15 mm.
Breadth	17 „	21 „

Considerable variations in size existed.

The average measurements of the sinuses in the series were —Mean Height, 33·6 mm.; Mean Breadth, 26·4 mm. The right sinus was on an average smaller than the left (Plate XXX. Fig. 2).

Sex.—In the female skulls the frontal sinuses were not so large as in the male, so that the average height and breadth of the sinuses in the male crania somewhat exceeded that of the series; the diameters in the male crania were—Mean Height, 34·9 mm.; Mean Breadth, 26·7 mm.; and in the female crania —Mean Height, 29·1 mm.; Mean Breadth, 23·4 mm.

Presence and absence.—One of the most interesting points disclosed in the examination of the Australian crania was the frequency with which one or both frontal sinuses were absent. The massive and overhanging supraciliary ridges which constitute so prominent a feature in the frontal region of these skulls consist in many instances entirely of bone, and do not conceal behind them well-developed sinuses (Plate XXX. Fig. 1). It is necessary to again emphasise the fact that these conclusions were only arrived at after boring holes in each sinus region, and that no reliance was placed upon the negative results of illumination. Of the 69 skulls examined, we find that both sinuses were present in 38 skulls, or 55 per cent., while both sinuses were absent in 21 skulls, or 30·4 per cent. The right sinus was absent in 9 skulls, or 13 per cent. The left sinus was absent in one skull, or 1·4 per cent.; that is to say, in 31 skulls, or 44 per cent., one or both of the sinuses were absent. If these facts be classified according to sex, we find that both sinuses were absent in 12 male and in 9 female crania, while one sinus was absent in 8 male skulls and in one female skull. In other words, the sinuses were absent in twice as many male as female skulls. As the total number of male crania more than doubled the female, one must conclude that the sinuses are somewhat more frequently absent in the female crania. Not only

PLATE XXX.

FIG. 1.—Australian cranium.

FIG. 2.—Australian cranium.

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was the right sinus more frequently absent than the left, but, as we have already indicated, the mean measurements of the right sinus showed it to be a smaller cavity than the left. In the Asiatic races, on the other hand, the right sinus was the larger, while in the Europeans sometimes the right, sometimes the left, was the larger cavity.

Comparison of the Frontal Sinuses in different Skull Types

If we now compare the height of the frontal sinuses in the Tapeinocephalic crania of Australia with that of the Akrocephalic skulls of Burma, China, and Siam, we find that in the former the mean height of the sinuses exceeds that found in the Akrocephalic skulls. Table IV. will show this at a glance :—

TABLE IV., *showing Relative Height of Frontal Sinuses in different Skull Types*

Race.	Skull Type.	Mean Height of Sinuses.
Australians . . .	In 9 Tapeinocephalic skulls	38·5 mm.
Burmese . . .	„ 22 Akrocephalic skulls	35·4 „
Chinese . . .	„ 8 „ „	27·0 „
Siamese . . .	„ 4 „ „	29·2 „

The sinuses are thus considerably higher in the Tapeinocephalic skulls.

Our investigations have now proceeded sufficiently far to permit of our making a comparison between the height and breadth of the skull and the height and breadth of the sinuses. In the European crania we have a low Height-Breadth index, the breadth of the skull considerably exceeding the height; in

the Burmese, Chinese, and Siamese, while the breadth of the skull still exceeds the height, the two diameters more nearly approximate to each other than in the Europeans. In the Australians, on the other hand, there is a high Height-Breadth cranial index, the vertical diameter of the skull being as a rule greater than the transverse diameter. The figures in Table V., indicating the Mean Height and Breadth of the sinuses, do not correspond to those already given as the mean of the different series. This is due to the fact that every skull in the series cannot be utilised for the purposes of comparison. If we tabulate the Mean Height and Breadth of the frontal sinuses in these three skull types, as has been done below, it will at once become possible to observe whether any relation exists between the cranial and sinus diameters. Of the European races we may select those containing the largest number of skulls.

TABLE V., *showing Measurements of Frontal Sinuses in different Skull Types.*

	Race.	Height-Breadth Index of Skulls.	Mean Height of Sinuses.	Mean Breadth of Sinuses.
A.	Scottish .	Skull breadth greater than height	29·2 mm.	26·2 mm.
	Irish .	" "	36·1 "	30·1 "
	French .	" "	33·3 "	28·1 "
	German .	" "	35·3 "	33·9 "
B.	Burmese .	Skull breadth greater than height, but more nearly approaches it	37·4 mm.	29·9 mm.
	Chinese .	" "	22 "	14 "
	Siamese .	" "	29 "	24 "
C.	Australian	Skull height exceeds breadth .	36·8 mm.	29·1 mm.

It is at once obvious that when the breadth of the skull exceeds the height, as in Section A. of the Table, the mean transverse diameter of the sinuses is not greater than the vertical. It is true that in individual skulls the breadth of a sinus may exceed its height, but this is exceptional. We find, further, that there is no tendency for the breadth and height of the sinuses to become more equal in those skulls in which these two diameters more closely approximate to each other, as in Section B. On the contrary, in the Burmese and Chinese crania especially, there is even a greater disparity between the height and breadth of the frontal sinuses than in those of the European crania. Lastly, a comparison of these figures will show that the breadth of the sinus does not increase with the breadth of the skull, nor does the height of the sinus increase with the height of the skull, as a comparison of the Irish and Australian sinuses will at once demonstrate. We are therefore led to conclude that there is no relation between the Height-Breadth indices of the skulls and the vertical and transverse measurements of the frontal sinuses.

D. THE TASMANIAN CRANIA

The Tasmanian crania, eight in number, consisted of seven male skulls and one female. Like the Australians, they were Dolichocephalic and Tapeinocephalic, and possessed a high Height-Breadth index, the height of the skull exceeding the breadth.

The Frontal Sinuses.—Unfortunately it was not possible to illuminate the frontal sinuses in more than one skull, consequently we cannot form any conclusion as to the average dimensions of the cavities in this race. Of the two sinuses which were measured in a male skull, the Mean Height was 34·5 mm. and the Mean Breadth 29 mm. They were

thus well formed, the left one being slightly larger than the right.

Like the crania of the Australians, many did not possess frontal sinuses, so that of the eight skulls in the series we find that both sinuses were present in four skulls, or 50 per cent., while both sinuses were absent in four skulls, or 50 per cent. The number in the series is too small to admit of a general classification upon this point, but it sufficiently indicates that, as in the Australian skulls, these cavities are frequently absent.

E. THE MAORI CRANIA

The Maori skulls were obtained partly from the North Island and partly from the South Island of New Zealand. Of a total of 35, 29 were male and six were female skulls. While possessing in a considerable degree the prominent supraciliary ridges so characteristic of the Australian crania, they presented certain points of difference in regard to the type of skull. While the majority of them were Dolichocephalic, many were Mesaticephalic, so that the mean cephalic index of the series, although Dolichocephalic, was considerably higher than in the Australians. Further, they were Metriocephalic, and the mean Height-Breadth index of the skulls was lower than in the Australian skulls. In one half the breadth of the skull exceeded the height, while in the remainder the height exceeded the breadth.

The Frontal Sinuses.—Owing to the difficulty in illuminating the frontal sinuses, it was possible to measure only a comparatively small number of them; in all 13 sinuses were measured. They did not possess any striking feature. The largest pair met with in one skull was—

	Right.	Left.
Height	36 mm.	35 mm.
Breadth	29 "	36 "

while the smallest pair measured—

	Right.	Left.
Height	31 mm.	32 mm.
Breadth	21 „	16 „

One of the two sinuses in a skull may, however, be of still smaller dimensions; thus the two lowest sinuses examined only measured 16 and 18 mm. vertically, while the two narrowest were 15 and 16 mm. The Mean Height in the series was 29 mm., while the Mean Breadth was 23·3 mm. They were, therefore, somewhat below the average size. The sinuses in the male crania were larger than in the female, and the left sinus was rather smaller than the right.

Presence and absence.—The frequency with which many of the skulls were found without frontal sinuses was again a remarkable feature. Thus out of the series of 35 skulls, both sinuses were present in 13 skulls, or 37 per cent.; both sinuses were absent in 13 skulls, or 37 per cent.; and the right sinus was absent in 9 skulls. Thus in 22 skulls, or in 62 per cent., one or both cavities were not developed.

In reference to the question of sex, we find that both sinuses were absent in 12 male crania and in one female cranium, while the right sinus was absent in seven male and in two female crania. After making due allowance for the disparity in the number of the male and female skulls examined, we find that a greater proportion of the male crania were devoid of sinuses.

F. THE CRANIA OF CERTAIN AFRICAN TRIBES

It will be convenient to consider under this general heading a number of skulls belonging to the Bushmen, Kaffirs, Hottentots, and Negroes obtained from different parts of the

African continent. They are 41 in number, and are made up in the following way :—

TABLE VI., *showing the Number of African Crania examined.*

Bushmen . .	8 skulls	6 male	2 female
Kaffirs . . .	9 „	8 „	1 „
Hottentots . .	9 „	6 „	3 „
Negroes . .	15 „	8 „	7 „
Total . .	41 skulls	28 male	13 female

The type of skull varied somewhat in the different races. The majority of the Kaffirs, Hottentots, and Negro skulls belonged to the Dolichocephalic type, while most of the skulls of the Bushmen, on the other hand, were Mesaticephalic. The Bush crania presented a low vertical index, being Tapeinocephalic, and in every case the breadth of the skull exceeded the height. They were further characterised by the absence of a prominent glabella and supraciliary ridges, and also by the fact that the forehead approached the vertical, while the vertex of the skull was somewhat flattened (Plate XXXI. Fig. 1). These points in connection with the Bush crania are especially referred to here, in order to emphasise the distinction between the type of skull and that of the Chinese, which we have already seen to be Brachycephalic and Akrocephalic.

The Frontal Sinuses.—In the crania of the African tribes now under consideration the frontal sinuses were fairly well developed, and in Table VII. the Mean Height and Breadth of these cavities are briefly stated.

PLATE XXXI.

FIG. 1.—Bushman cranium.

FIG. 2.—Bushman cranium.

FIG. 3.—Hottentot cranium.

FIG. 4.—Hottentot cranium.

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PLATE XXXII.

FIG. 1. —Kaffir cranium.

FIG. 2.—Kaffir cranium.

FIG. 3.—Negro cranium.

FIG. 4.—Negro cranium.

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TABLE VII., *showing the Average Measurements of the Frontal Sinuses in certain African Tribes.*

Race.	Mean Height of Sinuses.	Mean Breadth of Sinuses.
Bush race . . .	26·4 mm.	22·5 mm.
Kaffirs . . .	34 "	32 "
Hottentots . . .	32·3 "	28·6 "
Negroes . . .	28·4 "	24 "

In the Bush crania the sinuses were below the average, and were smaller than those found in the other three races. Their measurements more closely correspond to those of the sinuses in the Chinese than in any other races examined. This fact undoubtedly furnishes additional proof of what we have already pointed out, that we do not find any definite type of sinus peculiar to a particular form of skull. The Bush crania are Mesaticephalic and Tapeinocephalic, while the Chinese are mainly Brachycephalic and Akrocephalic. In the Kaffirs the frontal sinuses were somewhat above the average in both their diameters, and were considerably larger than the sinuses in the Negroes; in both these tribes the cephalic and vertical indices are the same (Plate XXXII.).

In the African races a considerable percentage of the skulls have no sinuses, although this is not so large as in the Australians, Tasmanians, and Maoris. This is shown in Table VIII.

TABLE VIII., *showing Absence of Frontal Sinuses in certain African Tribes.*

Race.	No. of Skulls.	Both Sinuses absent in	Right Sinus absent in	Left Sinus absent in	Per cent. of Skulls without one or both Sinuses.
Bush .	8	4	0	1	62·5 per cent.
Kaffirs .	9	2	0	1	33·3 "
Negroes .	15	0	4	0	26·6 "
Hottentots	9	2	2	0	44·4 "

The sinuses were as frequently absent in the one sex as in the other.

G. THE EGYPTIAN CRANIA

A number of Egyptian skulls were also examined, and the size of their frontal sinuses investigated. In the series of 20, 16 were male and four were female skulls. The chief points connected with these crania which bear upon the present investigation are as follows :—

Cephalic index	Dolichocephalic.
Vertical index	Tapeinocephalic.
Height-Breadth index . . .	Height greater than Breadth.
Mean Height of sinuses . . .	32·0 mm.
Mean Breadth of sinuses . . .	24·2 ,, (Plate XXXIII.).

The sinuses did not present any features of unusual interest. Here, as elsewhere, the mean height and breadth measurements of these cavities in the male skull exceeded those in the female. In a small proportion of the crania there were no frontal sinuses. Thus, out of 20 skulls the sinuses were absent in four, or in 20 per cent.

H. THE ESQUIMAUX CRANIA

These skulls were collected in part in Greenland and in part on the northern shores and adjacent islands of the American continent. Of a total of 19 crania, 18 were males, the remaining one being a female skull. The following points in connection with this series may be thus briefly tabulated :—

Cephalic index	Dolichocephalic.
Vertical index.	Metriocephalic.
Height-Breadth index . . .	Breadth greater than Height.
Mean Height of sinuses . . .	29·1 mm.
Mean Breadth of sinuses . . .	23·6 ,, (Plate XXXIV. Fig. 1).

In no individual skull did the frontal sinuses attain any

PLATE XXXIII.

FIG. 1.—Egyptian cranium.

FIG. 2. –Egyptian cranium.

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considerable size. In a large number, however, one or both of these cavities were absent. Thus, out of 19 crania, no fewer than eight, or 42·1 per cent., had both sinuses absent, while in one the right sinus and in another the left sinus was absent. If the two latter be added so as to obtain a percentage of the whole series, we find that in no fewer than 52·5 per cent. one or both of these cavities were absent. In the single female skull both the sinuses were present.

I. THE AMERICAN INDIAN CRANIA

It will now be convenient to consider together a number of skulls obtained both from the northern and southern portions of the continent of America. The greater number of these, 29 in all, belonged to certain of the Indian tribes of North America, amongst which may be mentioned the Chenooks, Apache, Hurons, Choctaw, and Sioux. A smaller proportion, 12 in all, came from South America. Two of these skulls were labelled South American Indian, while six were marked Peruvian, and four Fuegian. The Fuegian skulls were obtained from Punta Arenas, on the Straits of Magellan. Of the 41 crania which form the total, 35 were male and six were female. Owing to the artificial distortion which had been produced in a large number of these skulls by the compression of bands applied to the head during infancy, no attempt was made to group the skulls according to their cranial indices. The type of skull, however, of the North American Indian is Brachycephalic, and Sir William Flower has shown that the Peruvian skull has a similar form. The deformity produced by artificial means was evident not only in the crania of the North American tribes, but also amongst the Peruvians and in the two South American Indian crania. The question naturally arose as to how far the development of the frontal sinuses might be influenced by the pressure

applied to the frontal region of the skull, especially in those cases in which the forehead was markedly flattened. Investigation, however, soon revealed the fact that the development of these cavities had apparently been in no way influenced by the external compressing agent. In Figs. 2 and 3, Plate XXXIV., is depicted the skull of a North American Indian in which both the frontal and occipital regions were markedly compressed and flattened. The largest pair of sinuses in the whole series of Indian crania is readily marked out by illumination in this skull. In connection with this point, it must, of course, be borne in mind that these cavities do not reach above the supra-orbital margins until the seventh year of child life, consequently at a period subsequent to the application of the head bands.

The following facts are of interest in connection with the sinuses of these crania:—

TABLE IX., *showing Average Measurements of Frontal Sinuses in American Indian Crania.*

Race.	Mean Height of Sinuses.	Mean Breadth of Sinuses.
North American Indians	34·2 mm.	29·2 mm.
South American Indians and Peruvians .	32·3 „	21·7 „
Fuegians	30·4 „	18·0 „

In some of the North American crania the sinuses were very well developed, and attention has already been drawn to the largest of these on Plate XXXIV. Fig. 3. The measurements in this skull are—

	Right.	Left.
Height of sinus . . .	54 mm.	48 mm.
Breadth of sinus . . .	49 „	44 „

PLATE XXXIV.

FIG. 1.—Esquimaux cranium.

FIG. 2.—North American Indian cranium.

FIG. 3.—North American Indian cranium.

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Owing to the very small number of Fuegian skulls, it was not advisable to draw any conclusions from their mean measurements.

While there was practically no difference between the mean size of the right and left cavities in the above series, the sinuses in the male skulls slightly exceeded those in the female. It was further found that in a certain percentage of the skulls in the group of American Indians there were no sinuses present.

TABLE X., *showing Number of Frontal Sinuses Absent in American Indian Crania.*

Race.	No. of Skulls.	Both Sinuses absent in	Right Sinus absent in	Left Sinus absent in	Per cent. of Skulls without one or both Sinuses.
North American Indians .	29	4	3	1	27·5%
South American Indians and Peruvians	8	1	1	0	25%
Fuegians	4	0	0	1	25%

K. CRANIA OF SANDWICH ISLANDERS

All the skulls in this series, 35 in number, were obtained from the island of Oahu, one of the Sandwich group, situated in the Northern Pacific Ocean. Twenty of them were male crania and fifteen were female. Three distinct types of skull were met with among the islanders of Oahu, the Dolichocephali, Mesaticephali, and Brachycephali. These three types probably do not indicate the existence of three distinct races, the Mesaticephali being probably the result of intermixture of the other two types. Thus some approach more closely in form to the Dolichocephalic type, while others possess more distinctly the characters of the Brachycephalic. In the majority of the Dolichocephalic crania the height of the skull exceeded the breadth, while in all the Brachycephali the opposite condition existed.

The Frontal Sinuses.—Owing to the fact that a large number of the frontal sinuses failed to illuminate, on account of the thickness of their bony walls, a sufficient number of observations were not obtained in the two races to permit of any comparison being made between the sinuses in the Dolichocephali and Brachycephali. We have already shown, however, in other races that the frontal sinuses do not assume any special form in the different types of skull. It will suffice, therefore, to consider the development of these cavities in the whole group of the Sandwich Islanders, so far as their measurements permit of this being done. The sinuses were fairly well developed: their Mean Height measured 29·7 mm., while the Mean Breadth was 21 mm. It is interesting, however, to observe that amongst the Sandwich Islanders the mean height of the sinuses in the two sexes was the same, while in the female skulls the sinuses were broader than in the males. For this reason these cavities were somewhat larger in the female than in the male skulls.

Presence and absence.—Out of the 35 skulls, both sinuses were absent in three, or in 8·5 per cent., while in seven skulls the right sinus was absent, *i.e.* in 20 per cent. We find, therefore, among the Sandwich Islanders that one or both cavities were absent in 10 skulls, or in 28·4 per cent.; the percentage is not so large as in the Australian and Maori crania. The three skulls in which both sinuses were absent belonged to the female sex.

General Conclusions regarding the Frontal Sinuses, derived from an Examination of 578 *Skulls.*

We must now attempt to summarise, as briefly as possible, the numerous facts which have been gathered from an examination of the frontal sinuses in the skulls of the various races which have just been considered. It is true that in several

of these races the number of skulls examined was small, and therefore hardly permitted of generalisation with regard to them. On the other hand, in the British, French, Burmese, Australians, Maoris, American Indians, and Sandwich Islanders, whose skulls are sufficiently numerous, it is permissible to express an opinion regarding the racial features of the frontal sinuses. The grand total of 578 permits us, further, to draw certain general conclusions with regard to these cavities, quite irrespective of race.

The investigation shows that the sinuses possess no distinctive form or size which can be said to be peculiar to any of the great skull types, Dolichocephalic, Mesaticephalic, or Brachycephalic. Thus, in the Dolichocephalic skulls of New Zealand the average height and breadth measurements of the sinuses were almost identical with those found in the Brachycephalic Siamese. Other examples illustrating the absence of any distinctive form of sinus in the different skull types might be quoted. Again, we find that the greatest mean vertical measurements of the sinuses were obtained in the Burmese and Irish crania. The former are Akrocephalic skulls, while the latter are Tapeinocephalic. The lowest mean vertical measurements were found in the Bush race and the Chinese, the Bushmen being Tapeinocephalic and the Chinese Akrocephalic. Table IV., which we have already drawn out on page 87, demonstrates the fact that the sinuses are indeed higher in the Tapeinocephalic Australians than they are in any of the Akrocephalic Asiatic crania.

In comparing the Height-Breadth indices of the skulls with the height and breadth measurements of the sinuses, we again find that there is no relation between them. Proof of this has already been given in our summary of the Australian crania in Table V. on page 88. The following points, however, are not without interest. In all the races examined, with one exception,

the Height-Breadth index of the male skulls exceeded that of the female skulls, a condition which may reasonably be expected; in the Sandwich Islanders, however, this index was greater in the female than in the male skulls. The mean measurements of the frontal sinuses in the male exceeded those in the female skulls, with the exception of the Sandwich Islanders, in whom the converse existed. Therefore the greater cranial Height-Breadth index was associated with the greater height and breadth measurements of the sinuses. Again, we have also found that the mean Height-Breadth index of the skulls in which both sinuses were present was greater than the same index in the skulls in which there were no frontal cavities.

The investigation also proves that the frontal air sinuses are present in all the races of men, but that they occur with a varying degree of frequency. While marked extremes in size are met with in individual skulls, the average height and breadth measurements throughout the different races do not show any very striking variations. Table XI. will give at a glance the mean vertical and transverse diameters of the frontal sinuses throughout the different series :—

TABLE XI., *showing Average Measurements of the Frontal Sinuses in different Races.*

Race.	Mean Height of the Sinuses.	Mean Breadth of the Sinuses.
British	31·8 mm.	29·7 mm.
Irish	36·1 "	30 "
French	33·6 "	27 "
Germans	35·3 "	33·9 "
Swiss	35 "	29·1 "
Russians and Poles	30 "	22·7 "
Greeks	31·8 "	27·7 "
Turks	34·5 "	29·7 "
Europeans	33·5 mm.	28·7 mm.

Race.	Mean Height of the Sinuses.	Mean Breadth of the Sinuses.
Burmese	36·5 mm.	29·2 mm.
Chinese	26·2 „	20·5 „
Siamese	29·2 „	22 „
Chins and Lushais . . .	32·9 „	28·1 „
Asiatics	31·2 mm.	24·4 mm.
Australians	33·6 mm.	26·4 mm.
Maoris	29 „	23·3 „
Bush race	26·4 „	22·5 „
Kaffirs	34 „	32 „
Hottentots	32·3 „	28·6 „
Negroes	28·4 „	24 „
Egyptians	32 „	24·2 „
Esquimaux	29·1 „	23·6 „
North American Indians . .	34·2 „	29·2 „
South American Indians, including Peruvians . . .	32·3 „	21·7 „
Fuegians	30·4 „	18 „
Sandwich Islanders . . .	29·7 „	21 „

A study of these figures shows us that there is only a difference of 10 mm. (1 cm.), or practically half an inch, between the mean vertical measurements of the highest and lowest sinuses, *i.e.* 36·5 mm. in the Burmese series and 26·2 mm. and 26·4 mm. in the Chinese and Bushmen. In regard to the mean breadth, the difference is only slightly greater—from 33·9 mm. in the series of German crania, to 20·5 mm. in the Chinese skulls. Although the mean breadth of the sinuses in the Fuegian skulls is 18 mm., this group cannot be used for purposes of comparison, owing to the small number of sinuses which this figure represents. A glance at the Plates which illustrate the frontal sinuses will show the marked differences that may occur in the size of these cavities in individual skulls.

If an average be taken of the various means of the 24 races above tabulated, it is found that the Mean Height of the sinuses is 31·6 mm., while the Mean Breadth is 25·8 mm. These figures may be taken to represent the standard measure-

ments of the frontal sinuses which we have already laid down. The relative size of the left and right cavities varies in different races: in a small minority the two cavities are equal in size, but the left sinus is more frequently the larger.

Sex Characteristics. — In all those races in which it was possible to calculate the relative size of the frontal cavities in the two sexes, the mean measurements in the male skulls exceeded those in the female, with the exception of the sinuses in the Sandwich Islanders. The following figures show the relative difference in the two sexes:—

	Mean Height of Sinuses.	Mean Breadth of Sinuses.
Male Skulls . . .	33 mm.	26·2 mm.
Female Skulls . . .	27·6 „	22·1 „

The position of the Septum intervening between the frontal sinuses was ascertained in 355 skulls. In 277 instances it occupied the mesial plane throughout its whole length, while in 78 cases it deviated to one or other side of the middle line of the forehead. In 47 skulls the obliquity was to the right, while in 31 the septum was oblique to the left. As a rule, therefore, the septum is mesial in position. It is important, however, to bear in mind that in almost all the cases of obliquity of the septum, however marked it may be, that structure is mesial in position at its lower end immediately above the root of the nose. In only 13 instances did the septum lie altogether to one or other side of the mesial plane—in 8 cases being to the right, in 5 to the left. The distance from the mesial plane to the lower end of the septum in these cases varied from 2 to 9 mm.

Presence or absence. — In the detailed accounts of the

various races which we have already given, the number of skulls in which one or both sinuses were absent has been stated. It will be convenient to again tabulate these figures here under the following heads :—

TABLE XII., *showing Frequency of Absence of Frontal Sinuses.*

Race.	No. of Crania.	No. of Skulls with one or both Sinuses absent.	Percentage.
Crania of Great Britain and Ireland	160	31	19·3 per cent.
Crania of European continent .	80	10	12·5 "
Crania of Europe . .	240	41	17 per cent.
Crania of Asiatic races .	70	12	17 "
Australian crania . . .	69	31	44·8 "
Tasmanian crania . . .	8	4	50 "
Maori crania	35	22	62 "
Crania of African tribes—Bush, Hottentot, Kaffirs, Negroes .	41	16	39 "
Egyptian crania . . .	20	4	20 "
Esquimaux crania . . .	19	10	52·6 "
North American Indian crania	29	9	31 "
South American Indian crania	8	2	25 "
Fuegian crania	4	1	25 "
Crania of Sandwich Islanders .	35	5	14·2 "
Total	578	157	27·1 per cent.

Out of 578 skulls, 157, or 27·1 per cent., had one or both sinuses absent. These figures, however, bring out in a striking manner the marked difference between the crania of the European and Asiatic peoples on the one hand, and those of the aboriginal tribes of Australia and New Zealand on the other. As a comparatively large number of skulls was examined in the Australians and Maoris, we may with justice regard the absence of the frontal sinuses as a characteristic racial feature in them. Amongst the Tasmanians and Esquimaux a very similar condition existed, but in these races a comparat-

ively small number of skulls was examined. The right frontal sinus was found to be absent three times more frequently than the left. This was especially noticeable in the Australian and Maori skulls, in whom, as we have already seen, the mean measurements of the right sinus were smaller than those of the left.

In comparing the non-development of the sinuses in the two sexes, we find that one or both cavities were absent in 129 male skulls and in 38 female skulls. The actual number of male crania examined was 457, and of female crania 116, the sex in five being doubtful. The sinuses are therefore more frequently absent in the female crania.

With regard to the *type of skull* in which absence of *both* sinuses was most common,—and this comprises a total of 80 skulls,—the majority or 44 were found amongst the Dolichocephali, which included such races as the Australians, Tasmanians, Maoris, and Esquimaux. Amongst the Mesaticephalic, 26 skulls, and amongst the Brachycephalic, 10 skulls, had no sinuses. Throughout the different series we find that there were 231 Dolichocephalic, 182 Mesaticephalic, and 112 Brachycephalic skulls. Therefore both sinuses were absent in 18·6 per cent. of the Dolichocephali, 14·2 per cent. of Mesaticephali, and 8·2 per cent. of Brachycephali.

The Relation of the Frontal Sinuses to the Ophryon and Glabella

In determining the Cephalic or Length-Breadth index of a skull, that is to say, the relation between its antero-posterior and transverse diameters, craniologists have not always based their calculations upon the same points of measurement. While all anthropologists agree with regard to the method of measuring the greatest transverse diameter of the skull, and

further accept the mid-occipital point as the area on the posterior aspect of the skull, there is not the same unanimity with regard to the area to be selected in the region of the forehead. Thus, some authorities record their measurements from the mid-occipital point to the nasion, or the union of the two fronto-nasal sutures. Sir William Turner, in his *Report on the Human Crania collected by H.M.S. "Challenger,"* takes the glabella or the area of greatest prominence upon the forehead. He thus writes: "To ignore the glabella in estimating the extreme length of the cranium, is to leave out of consideration an eminence which in many skulls and heads constitutes one of the most noticeable features in the frontal region, and which is so frequently an important sexual character. Moreover, it seems to me that with the skull, as with the living head, our object should be to compare the greatest length and greatest breadth with each other whenever they occur, and not to confine our measurements to those parts of the skull which more directly form the wall of the brain cavity."

Rolleston and Flower, on the other hand, made use of the ophryo-occipital diameter. The ophryon, or supra-orbital point, is the area of bone lying immediately above the glabella. If a horizontal line be drawn across the mesial plane of the forehead so as to connect the highest points of the two supraciliary ridges, the point at which this line intersects the mid plane is the ophryon. Rolleston, in justifying his choice of this area in making the antero-posterior measurements of the skull, says: "This appears to be the most reasonable spot to take for an antero-posterior measurement of the brain-case, as the applied area of the compasses comes there into nearer relation with the cavity containing the cerebrum than at either of the two other points specified (glabella and nasion)."

In carrying out this investigation into the comparative anatomy of the frontal sinuses in the human crania, one could

not fail to be struck by the frequency with which these cavities were not limited to the region of the glabella and supraciliary ridges, but extended upwards in the frontal region behind and above the ophryon. Closer inquiry into the relation of the sinus to the ophryon revealed the fact that it was the exception to find that the sinus did not reach so high as that area. Consequently it follows that the frontal sinus intervenes between the two tables of the frontal bone, not only behind the glabella, but also behind the ophryon, and therefore the ophryo-occipital measurement does not indicate precisely the antero-posterior diameter of the cranial cavity.

Careful measurements were made in 174 skulls in which the frontal sinuses were present, in order to obtain accurate evidence on this point. It was found that in 130 skulls the sinuses extended above the ophryon, while in 32 the upper limit of the sinus lay immediately behind that area. On the other hand, in only 12 skulls did the sinuses fail to reach so far upwards upon the forehead. In other words, the frontal sinuses intervened between the outer and inner tables of the frontal bone behind the ophryon in 162 skulls, or in 93·1 per cent., while in 12 skulls, or in 6·8 per cent. of the cases, the sinuses did not extend upwards to the level of this area (Plate XXXV.).

These points are also well illustrated in a number of the Plates on which the frontal sinuses are figured (see Chapter II.). In these the anterior wall of the cavities has been removed; in others, again, the extent of the sinuses is mapped out by illumination (*e.g.* Plate XXXVII.). The height of the sinuses above the ophryon varied from 2 mm. to 30 mm. The average extension of the sinus above the ophryon was 7·9 mm.

In order to estimate to what extent the interposition of the sinus between the ophryon and the inner table of the frontal bone will influence the cranial measurements, it is

PLATE XXXV.

FIG. 1.—Skull, showing frontal sinus extending upwards above the ophryon.

FIG. 2.—The other half of the same skull.

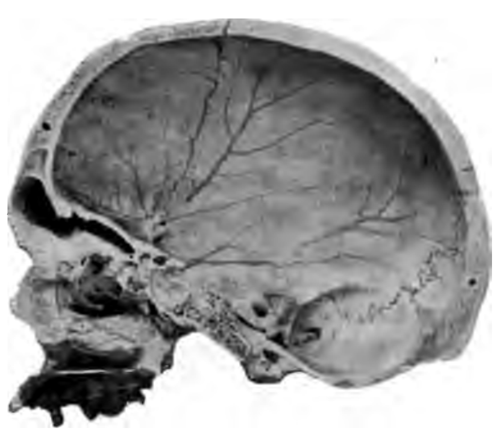

FIG. 3.—Skull, showing great depth of frontal sinus behind glabella and ophryon, and extension along roof of orbit.

[*To face page* 106.

necessary to calculate the depth of the cavity in that region. For this purpose, it was found possible to measure the depth of the sinus behind the ophryon in 71 skulls. These measurements varied from 2 to 16 mm., the latter figure, however, being somewhat exceptional. The average depth obtained in the 71 skulls was 5·2 mm., or half a centimetre. If we compare these figures with those representing the depth of the sinus behind the glabella in the same series of skulls, we find that the measurements varied from 3 to 18 mm., the average depth being 8·5 mm. These figures, therefore, show that not only does the frontal sinus extend above the ophryon in the majority of skulls, but that the cavity may attain a considerable depth behind that area. For these reasons the ophryo-occipital diameter does not express the antero-posterior diameter of the brain cavity. The reason for selecting it, instead of the glabello-occipital diameter, in measuring the length of the cranium, as giving a clue to the length of the brain, is not supported by observation.

CHAPTER VII

TRANSILLUMINATION OF THE ACCESSORY SINUSES OF THE NOSE

I. Transillumination of the Maxillary Sinus

During the last ten or twelve years considerable interest has been centred round the question of transillumination of the nasal sinuses, and various opinions have been expressed as to its practical utility in the diagnosis of inflammatory affections of these cavities. By the term transillumination—the German *Durchleuchtung*, or through-illumination—we understand the passage of rays of light through the walls of a cavity from one surface to another. In 1888, Voltolini[1] of Breslau demonstrated the fact that luminous rays could be transmitted through the bony walls of the antrum of Highmore. In 1889, Heryng[2] of Warsaw elaborated this experiment, and placed illumination upon a practical working basis. Since that time numerous observers have recorded their experiences, and transillumination has become a routine practice in suspected cases of disease of the maxillary sinus.

Technique of the Examination.—In order to carry out this method of examination, a small electric lamp is required, producing a bright white light. I am in the habit of using an 8-volt lamp of about 1 ampère current. It is impossible with

[1] *Breslauer ärztlich. Ztschr.*, 1888, No. 22.
[2] *Berl. klin. Wochenschr.*, 1889, Nos. 35 and 36.

PLATE XXXVI.

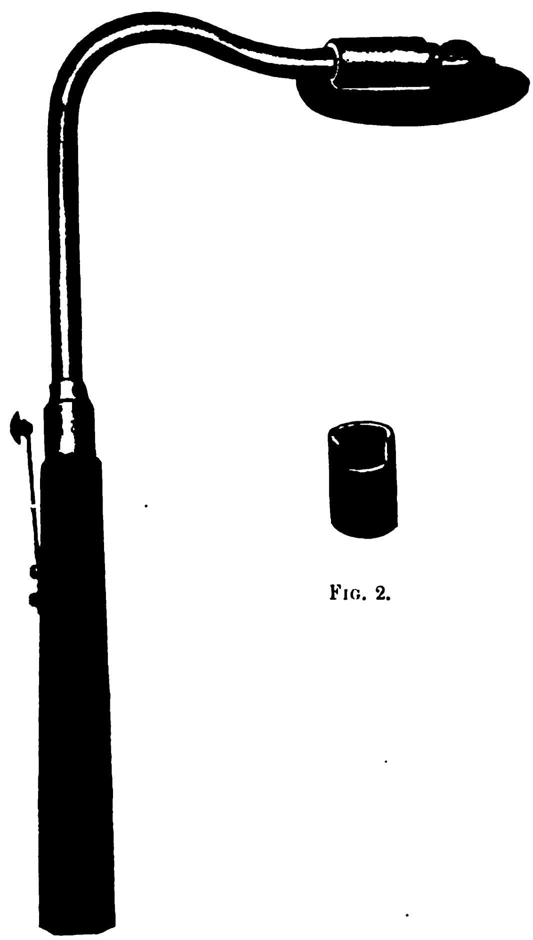

FIG. 1.

FIG. 2.

Lamp for transillumination of maxillary and frontal sinuses.

[To face page 109.

a small lamp of this kind to accurately estimate the candle-power employed, but due care should be taken to insure that the film is incandescent. The electricity may be obtained from a suitable accumulator, which can be carried about without very much inconvenience, or from an ordinary bichromate battery of six cells. An accumulator was used in nearly all the anatomical and experimental work recorded here, as well as for purposes of clinical observation. The lamp is fixed to the special form of tongue-depressor introduced by Reiniger, and is provided with a detachable vulcanite plate to prevent the lamp heating or burning the tongue. By means of a button in the handle of the instrument, the electric current can be established (Plate XXXVI. Fig. 1).

Great care must be taken during the examination to exclude all extraneous sources of light. This may be done either by darkening the room, or by enveloping the head and shoulders of the patient, along with those of the observer, in a black cloth. If a dental plate is worn by the patient, it must, in the first instance, be removed. The lamp is then introduced into the mouth, and slight pressure is made upon the dorsum of the tongue, the individual being directed to close his lips upon the stem of the instrument. It is better, also, that the individual should at the outset keep his eyes shut. The electric current is then induced. Three phenomena of illumination may be met with in healthy antra if the rays of light traverse the maxillary sinus and penetrate its roof. In the first place, the rays become visible to the observer upon the cheeks of the person under examination in the form of a small, often crescent-shaped, zone of light, situated in the region of the lower eyelid towards its inner part. This area of illumination, like the other phenomena to be presently described, is due to the passage of the light-rays through the roof of the antrum, *i.e.* the orbital floor. It varies in size, in shape, and in intensity,

but it forms the important factor in the objective examination of the face. In most cases the light is transmitted through the soft tissues of the cheek, producing a considerable area of illumination on each side—a result, however, which may be obtained independently of the antrum.

Again, the rays having penetrated the roof the antrum, may pass through the coats of the eyeball, so that they fall upon the retina, and are perceived by the individual as a subjective sensation of light. This phenomenon of illumination was first pointed out by Brown Kelly [1] of Glasgow in 1892, and was shortly afterwards noted by Garel [2] in France and Burger [3] in Germany. If the eyes be then opened, it may be possible for the observer, on looking through the pupils, to see the dull red reflection that is produced, a sign to which attention was drawn by Davidsohn.[4]

A comparison of the results observed upon the two sides of the face must then be made. In a healthy condition of the maxillary antra, both cavities are, as a rule, illuminated, the bright area of transmitted light being visible beneath each eye. Certain pathological conditions may prevent the transmission of light, such as the presence of pus in the cavity, a thickened condition of its lining membrane, or the existence of a solid antral growth. When a unilateral affection of this nature is present, the opposite healthy side alone illuminates, and a distinct contrast between the two sides is thus obtained. For this reason illumination has been adopted as a diagnostic aid.

Transmission of the light rays.—It is necessary at this stage to consider how the luminous rays pass from the mouth

[1] *Glasgow Med. Journ.*, February 1892.
[2] *Ann. des Malad. de l'oreille*, etc., 1893, No. 2.
[3] *Monatsschr. f. Ohrenheilk.*, Berlin, 1893, No. 11.
[4] *Berl. klin. Wochenschr.*, S. 665, 1892.

to the antrum and orbit. With the exception of a very small portion of the outer edge of the palatal plate of the superior maxilla, close to its alveolar margin, the roof of the mouth forms the floor of the nose, and takes no part in the formation of the floor of the antrum, this wall being formed by the alveolar process which bears the teeth. When the lamp is placed in the mouth, some of the luminous rays enter the maxillary sinuses directly, while the remainder pass into the nasal cavities, and thence reach the antra through their nasal walls. After traversing the cavity of the antrum, they penetrate its roof, which also forms the floor of the orbit. If the rays be sufficiently powerful, they then pierce the coats of the eyeball and fall upon the retina. These facts can be proved by the following simple experiments upon the skull. If the lamp be placed beneath the palatal plates, its rays will be observed to penetrate these bones, and also to illuminate both the anterior wall and the roof of each antrum. If the nasal chambers be then plugged with dark-coloured worsted or wool, the intensity of the light transmitted through the antral cavities is found to be diminished. It is further found that if the packing is confined to the floor of the nose, or to that portion of the chamber which is situated beneath the inferior turbinated bone, the diminution in the intensity of the light is greater than when the middle region of the nose alone is packed. This would indicate that the rays which pass from the nasal chamber into the antrum do so mainly through the outer wall of the inferior meatus. The practical importance of this observation will become more evident when we study the influence of nasal obstruction upon antral illumination.

Further experiments of a somewhat similar nature were also carried out upon healthy individuals. The antra were illuminated in the manner above described, and the result noted both

by the observer and by the person under examination. The inferior meatus of the nose on one side was then plugged with gauze. If equality in the intensity of the illumination upon the two sides had been previously noticed, it was frequently found by the observer that the illuminated area upon the cheek became less bright upon the obstructed side, while the individual illuminated was conscious of some diminution of the subjective sensation of light upon the side on which the nose was plugged. It was also found, when the antra were illuminated in the macerated skull, that if the lamp was held to one or other side of the mesial plane of the palate,—that is to say, more directly underneath one antrum,—the intensity of the illumination was somewhat increased upon the side more immediately above the lamp. This fact points to the necessity of exercising some care in placing the lamp within the mouth.

Escat's Method of Illuminating the Antrum.—In order to exclude the possibility of error in illumination of the antrum, arising from the passage of some of the rays of light through the nasal chambers, Escat[1] of Toulouse has introduced a method of illuminating these cavities, which he has named Retro-Maxillary Illumination. For this purpose the lamp is placed in contact with the posterior wall of the antrum, so that all the rays directly enter that cavity. The lamp is covered with a metal funnel, so that the rays pass from it in one direction; in this respect it resembles the lamp used in illumination of the frontal sinus. It is fixed at right angles to a stem which can be readily fitted into a galvano-cautery handle. The patient is directed to partially open his mouth; the finger of the operator, or the blade of a tongue-depressor held vertically, is then introduced in order to separate the cheek from the alveolar aspect of the maxilla. If the mouth is opened widely, the cheek is rendered too tense, and the introduction of the lamp

[1] *Revue Hebdomadaire de Laryngol.*, July 10, 1897.

is thus interfered with. The instrument is then passed along the outer aspect of the alveolar border of the upper jawbone, with the long axis of the funnel held vertically. When the interval between the cheek and the last two molar teeth is reached behind the malar ridge, the lamp is partially rotated, so that the open end of the funnel may be pressed against the superior maxilla in that situation. Contact is then made, and the phenomena similar to those above described are looked for. If this manœuvre be carried out with care, it does not prove painful to the patient, nor is the heat of the lamp a source of inconvenience if the séance is not too prolonged.

By this method all the rays undoubtedly enter the maxillary antrum directly; nevertheless, undue importance must not be attached to the possible fallacy arising in connection with Heryng's illumination. We have all probably seen antra illuminate in cases in which the nasal chambers contained polypi, and in which there has been no associated antral suppuration. Experiment also has shown us that while obstruction of the nasal chamber undoubtedly influences the intensity of the illumination in the antrum, the rays pass more readily into the latter cavity through the outer wall of the inferior meatus than through the nasal wall above the inferior turbinated bone,—that is to say, below the region of hypertrophies of the mucous membrane of the middle meatus and of polypi. The possible fallacy with regard to polypi may, however, be overcome in the following way. If in a suspected case of antral suppuration the nasal chamber should contain polypi, we probably find it necessary to remove them in whole or in part before being able to diagnose the condition of the antrum. If that cavity, previous to the removal of these growths, failed to illuminate, and still proved negative afterwards, *cæteris paribus*, the opacity would strongly suggest the existence of disease in that sinus. On the other hand, if opacity of the

8

antrum disappeared after the removal of the polypi, the inference would be that the absence of illumination had depended upon their presence in the nose, and that in all probability the sinus was healthy.

Results obtained by Transillumination of the Antra in Normal Conditions.—It is necessary to have some knowledge of the phenomena of illumination in health in order to properly appreciate its value in the diagnosis of disease. Anatomical variations are met with in the antra which must necessarily influence the intensity of the illumination not only in different skulls, but on the two sides of the same skull. As we have already seen in Chapter I., the cavities may be enlarged by the formation of recesses in the alveolar processes of the maxillæ, or by their extension into the palatal plates of these bones. The walls are consequently thin, and the rays are transmitted with greater intensity in such cases. On the other hand, the cavities may be reduced in size, and their bony walls considerably thickened, so that the intensity of the illumination is much diminished, or is altogether prevented. Asymmetry of the antra may lead to certain differences upon the two sides of the same skull. Of 54 macerated skulls which were illuminated, it was found that in 29 the antra illuminated equally on the two sides, in 16 there was some inequality in the intensity of the illumination, but both antra illuminated. In six skulls there was opacity on both sides, while in three only was one antrum opaque while the other transmitted the rays.

The examination of a number of presumably healthy persons enables us to note certain variations in the illuminating capabilities of the maxillary sinuses. Thus the brightness of the area may be of considerable intensity upon the two sides of the face in some persons, while in others the brilliancy is less pronounced. The more intense illumination is not confined to

women, as in them feeble illumination is sometimes observed, while an area of considerable intensity may be apparent in men. The thickness of the soft tissues of the face undoubtedly influences the brilliancy of the light. The size and shape of the illuminated area also vary, but this is not a point of so much clinical importance. Complete absence of illumination sometimes occurs. It is more common to find this upon both sides of the face than upon one side only, an observation which bears out the results noted upon the skulls. In my experience we rarely find one antrum opaque while the other illuminates. Some slight differences in the intensity of the illumination on the two sides in health is not infrequently observed, but the contrast in the majority of these cases is not a striking one.

The subjective sensation of light observed by the individual upon whom the test is applied, also varies. When intelligent persons are examined, we may find that they corroborate the examiner's objective observations. Thus, when both cheeks illuminate with equal intensity, the subjective light sensation may also be the same in both eyes. Again, if one cheek illuminates better than the other, the sensation of light may be more brilliant on the brighter side. On the other hand, the area of illumination may be visible under each eye, but the individual may not be conscious of any light sensation. This is more frequently the case when the intensity of the illumination upon the cheek is not pronounced. Comparatively few observations were made with regard to the presence of the red glow seen through the pupil, so that further comment upon this point will not be made.

The Results obtained by Transillumination in Diseased Conditions of the Antrum.—Notwithstanding the variations that may be met with in the illumination of healthy antra, this test undoubtedly affords valuable assistance in the detection of suppuration in the antrum. It must, however, be dis-

tinctly understood that the test is only employed to strengthen the other clinical signs of disease that may be present, and that opacity of the antrum must not be taken by itself to imply the existence of a morbid condition of that cavity. The following observations have been made upon patients in whom it was subsequently proved by operation that an inflammatory condition of one or both antra was present.

Through the kindness of Dr. M'Bride, I have been able to supplement my own cases, and in this way can analyse my observations based upon 60 patients. In 52 of these the suspected antrum did not illuminate; of this latter number the opacity on the diseased side formed a distinct contrast to the illumination of the opposite healthy side in 40 cases. In three, the healthy side illuminated feebly, so that there was no marked contrast between the two cavities. In two the opposite healthy side, like the antrum containing pus, was opaque. Lastly, in seven the affection was bilateral, so that no comparison was possible.

In the remaining eight cases, on the other hand, the affected antrum showed some degree of illumination. In six of them the affection was unilateral: of these, five exhibited a distinct contrast with the opposite healthy side, which illuminated brightly, while in one there was a feeble illumination on both sides, and therefore no information was to be derived from a comparison of the two sides in this case. In the other two cases the disease was bilateral, and there was faint illumination upon both sides.

We find, therefore, that out of 51 cases of unilateral affection of the antrum, illumination showed that a marked contrast existed between the result obtained on the diseased and that on the healthy side in 45, or 88·2 per cent., of the cases. In the remaining six, or in 13·3 per cent., there was no contrast obtained, owing to the fact that illumination showed similar

features upon the two sides. We are thus able to divide the results obtained in unilateral affections into two groups. The first, and by far the larger, includes those cases in which the illumination test provides a distinct contrast upon the two sides. If this occurs in conjunction with other intra-nasal signs which strongly suggest that the pus is coming from the antrum, the surgeon does not require the assistance of exploratory puncture of the cavity to confirm his diagnosis. On the other hand, there is a second and considerably smaller group of unilateral affections, in which either the intensity of the light on the two sides is more or less equal, or in which neither antrum illuminates. In such cases the surgeon will receive little or no assistance from the illumination test, and will prefer to make an exploratory puncture of the antrum in order to satisfy himself as to its condition.

There were in all nine cases of bilateral affection. In seven of them the antrum on each side did not illuminate; in the remaining two there was some degree of illumination. In bilateral affections the test is not of the same clinical value, as no comparison is possible between the two sides. Moreover, in our experience, opacity of both antra occurs more frequently than unilateral opacity from anatomical causes. At the same time, if the other clinical signs point strongly to an affection of both antra, the absence of illumination must necessarily strengthen our views with regard to diagnosis.

In only 25 of the cases was any inquiry made as to the subjective light sensation perceived by the patient. In 22 of these this test corroborated what the observer himself noted in his objective examination of the face. When the antrum was opaque, the patient as a rule did not perceive any light in the eye of the affected side. In three instances of unilateral disease, however, in which no area of light was visible upon the cheek, the patient asserted that he had a faint light

sensation upon the opaque side which distinctly contrasted with the brighter light perception in his other eye. One has naturally some difficulty in crediting the observation of these patients. In conclusion, we must repeat that the illumination test is one of very considerable diagnostic value.

There can be no doubt that in cases of chronic suppuration of the antrum, non-illumination is due more to the infiltration and thickening of the mucous lining of the cavity than to the actual presence of pus within it. This is shown by the fact that, after a quantity of pus has been washed out of the antrum and the illumination test is again repeated, the opacity remains. For the same reason, the consistence and the quantity of the pus bear no relation to the density of the shadow produced. It has been suggested that in those cases in which the antrum merely serves as a reservoir for pus secreted in the frontal sinus, opacity of the cheek is less pronounced than when it is actually secreted in the antrum itself. I have been unable to satisfy myself of this, and am inclined to think that an antrum cannot long remain merely a reservoir, but must soon become itself actually infected.

Illumination further assists us in arriving at a knowledge of the progress of the case towards recovery. When a diseased cavity, treated by lavage and previously opaque, is found to illuminate, we have evidence of the restoration of its lining membrane towards a more normal condition. It will suffice to give one illustration of this. A patient, in whom suppuration of the left antrum was diagnosed, presented the following phenomena prior to operation. The right antrum illuminated, and a subjective light sensation on the same side was perceived by him. The left antrum was opaque, and no subjective sensation was observed. The case was treated by irrigation through an alveolar opening for three months. At the end of that time no evidence of suppuration could be detected.

The left antrum was then found to illuminate, and the patient for the first time was conscious of the sensation of light on the left side. Neither phenomenon, however, presented the same intensity as on the opposite healthy side.

In the differentiation of a cystic from a solid growth of the antrum, transillumination is an additional aid to the other clinical signs that may be present. When a solid growth involves the antrum, there is opacity on the side of the lesion. In the case of the cyst, the illumination is intensified upon the diseased side. This was beautifully illustrated in two cases of cyst of the antrum which I had the opportunity of illuminating. One of them was under the care of Mr. Cathcart, and the other was kindly sent to me by Dr. Lovell Gulland for treatment. In both cases the facial wall of the superior maxilla was expanded and thinned. It is sometimes asserted that transillumination by Heryng's method will assist the surgeon in differentiating between a tumour that is confined to the nasal chamber, and one which, starting in the nose, has involved the antrum in its growth. Exception must be taken to this statement, as the result will depend partly upon the seat of origin of the tumour, and partly upon whether it completely fills the whole nasal cavity or not. In a case of papilloma of the left nasal chamber recently under the care of Dr. M'Bride, which did not involve the left antrum, I found the latter cavity quite opaque to the light rays, and offering a distinct contrast to the opposite side. Further, the patient experienced no subjective light sensation, such as she observed on the right side. The tumour completely filled the left nasal chamber and extended into the naso-pharynx. After its removal there was a marked change observed in the illumination. The left antrum was then seen to transmit the rays, and the patient for the first time was conscious of a sensation of light in the left eye.

II. Transillumination of the Frontal Sinus

Owing to the varied opinions which have been expressed with regard to the value of transillumination in the diagnosis of disease of the frontal sinus, it is necessary to study the subject in its anatomical as well as in its clinical bearings. In this way only is it possible to ascertain the cause of the different statements which undoubtedly are made in connection with this procedure.

It has been shown by Vohsen[1] that the rays of light may be transmitted through the frontal sinus from an electric lamp placed against the orbital surface of the floor of the cavity. As a result of this procedure, an illuminated area is produced upon the anterior surface of the forehead immediately above the root of the nose and inner part of the supra-orbital margin. The light rays cannot be passed through the frontal cavities from a lamp placed in the mouth, as has been suggested. We shall in the first place study the different methods employed in the illumination of the frontal sinuses.

Technique of the Examination.—A lamp similar to that used in illumination of the maxillary sinus is employed in this procedure. The vulcanite plate, however, is removed, and a small funnel of metal, vulcanite, or some other material is substituted for it. This is fitted over the lamp so that the rays pass in one direction only, namely, from the open end of the funnel. A piece of indiarubber tubing is preferred by some for this purpose. I am in the habit of using a funnel of ivory, blackened both on its inner and outer surfaces, and have found it very serviceable (Plate XXXVI. Fig. 2). In fitting on this funnel, care should be taken that it projects a short distance beyond the globe of the lamp, so that the latter does not come in contact with the skin of the person under

[1] *Berl. klin. Wochenschr.*, 1890, No. 12.

examination. Unfortunately, a certain amount of heat is conducted through the funnel, so that one must be careful not to keep it for an inconveniently long period in contact with the skin. The room must be darkened, or the head and shoulders of the patient and of the observer must be covered with a black cloth.

The open end of the funnel is then placed against the floor of the frontal sinus, that is, against the roof of the orbital cavity, a short distance above and slightly external to the inner canthus of the eye. The application of the lamp requires some care, if the best results are to be obtained. The thickness of the bone forming the floor of the sinus varies somewhat in different situations, but as a rule there is an area of bone thinner than the rest, through which the light more readily passes. As there is no anatomical landmark which will serve as a guide to this thin area, I have found that the distance of its inner margin from the middle line of the nose at its root measures 17 mm., or slightly less than $\frac{3}{4}$ of an inch. The inner edge of the funnel should therefore not be placed nearer the mesial plane of the nose than this point. Again, it is very necessary that the lamp should be placed well under the supra-orbital bony margin. Unless this is done, there is a tendency for part of the rays to pass through the superficial soft tissues of the forehead, thus lighting them up and giving a false impression with regard to the results of illumination. When the lamp is applied gently but firmly, the direction of the funnel should be inwards, upwards, and somewhat backwards.

When contact is made and the rays of light penetrate the floor of the sinus, they traverse the cavity, and, passing through its anterior wall, give rise to an illuminated area of varying size and intensity upon the lower part of the forehead. This area of light is situated above the inner end of the supra-orbital margin, and is usually limited to one side of the mesial

plane. If the lamp be then placed beneath the supra-orbital margin of the opposite side, a similar area of illumination may become visible above it.

The significance of these illuminated areas was first pointed out by Kuhnt,[1] who showed that they delineated the frontal sinuses. I have had ample opportunity of proving the accuracy of Kuhnt's observation, by first illuminating and then opening a number of frontal sinuses, not only in macerated skulls, but also in the cadaver, as will be presently detailed. The illumination test is employed in suspected cases of disease with the object of determining whether the cavity secreting pus fails to transmit the rays of light, so as thus to present a contrast to what is seen on the opposite healthy side. To what extent this occurs, subsequent description will reveal.

In the method just described, a simultaneous illumination of both cavities is not obtained. For this reason, it is maintained by some that a sufficiently accurate picture of bilateral illumination is not possible, and that consequently a comparison of the two sinuses is rendered difficult. To obviate this objection, an apparatus has been devised by Lubet-Barbon and Furet,[2] by means of which the rays are conducted from a single lamp along two tubes bifurcating from a common stem. These are applied simultaneously to the floor of each sinus, so that both cavities are illuminated together.

These observers have also practised a method of illumination which they term the "médio-frontal." A lamp is placed in the mesial plane of the forehead from 2 to 3 cm. above the root of the nose. Under certain conditions the rays of light, travelling in the opposite direction to that above described, illuminate simultaneously the floor of each sinus beneath the supra-orbital margin. The observer is in this way able to detect variations in the intensity of the illumination upon the

[1] *Loc. cit.* [2] *Ann. d. mal. de l'oreille, du larynx, etc.*, Paris, June 1899.

two sides. If the edge of the hand be pressed against the forehead between the lamp and the root of the nose, the rays of light which illuminate the skin upon this part of the forehead are concealed from view, and the illumination of the floors of the sinuses is rendered more obvious.

Acting upon a suggestion made to me by Dr. M'Bride,[1] I have for some time experimented with the object of demonstrating a subjective light sensation in frontal sinus illumination similar to that obtained in illumination of the maxillary antrum. For this purpose the lamp was placed alternately upon the anterior wall of each frontal cavity, and the individual was directed to close his eyes, and asked to note the presence of a light sensation, first in one and then in the other eye. The rays penetrating the floor of the sinus from above downwards, and passing through the coats of the eyeball, fell upon the retina, and were perceived as a luminous glow. The light rays spreading superficially from the lamp were prevented from reaching the eyes by firmly pressing the soft parts against the bony supra-orbital margin with a piece of cardboard. In many cases the results thus obtained corroborated the objective examination.

Having thus indicated the different methods which have been employed for illumination of the frontal sinus, we must now proceed to investigate the accuracy of Kuhnt's observation, and consider how far illumination may be of clinical value.

Results obtained by Transillumination of the Frontal Sinuses in Skulls.—A study of illumination upon the macerated skull demonstrates beyond dispute that in a very large proportion of cases these cavities can be accurately mapped out upon the forehead region, and the position of the intervening septum defined. The results obtained by illuminating 71 sinuses, mapping out upon the bone the areas thus defined,

[1] *Edin. Med. Journ.*, April and May, 1898.

and subsequently opening the cavities by removal of their anterior wall, or by some other means, are as follows :—

Fifty sinuses were found to be accurately illuminated: thirteen sinuses were somewhat larger than the illumination suggested; one was slightly smaller than the area defined by the illumination; in five the result was negative, the sinus, though present, failing to illuminate in each case. Lastly, in two the illumination gave a negative result, because no sinus existed. With regard to this last point, it is well to emphasise, from the outset, that when the frontal sinus is absent, there is no area of illumination if the test is properly applied.

When the frontal sinus is accurately delineated upon the skull, a very pretty demonstration of its dimensions is obtained: the septum is defined lying mesially or obliquely (Plates XXXVII. and XXXVIII.), and the wavy outline of the sinus, with or without the indication of small partitions jutting into its interior, can be traced from the upper end of the septum downwards and outwards to the supra-orbital margin (see Figs. on Plate XXIX.). The whole anterior wall of the sinus may illuminate with equal intensity, or parts thicker or denser than the rest may be depicted with less brilliancy, the supraciliary ridge being frequently mapped out as a shaded area. If the bone is very thin, the rays of light passing through the intervening septum may illuminate the cavity of the opposite side more or less accurately, with an intensity which is, as a rule, considerably less than that seen over the cavity primarily illuminated. The junction of the lighter with the darker area of illumination indicates the position of the septum.

The intensity of the illumination varies not only in different skulls, but on the two sides of the same skull. The variation is due to differences in the thickness and in the density of the bone forming the floor and anterior wall of the cavity, especially the latter. Bone which is porous and soft, though

PLATE XXXVII.

FIG. 1.—Frontal sinuses and septum mapped out by illumination.

FIG. 2.—The same skull, showing the sinuses opened and the accuracy of the illumination.

[To face page 124.

PLATE XXXVIII.

FIG. 1.—Skull of German. Left frontal sinus mapped out by illumination. There is no right sinus.

FIG. 2.—Skull of Negress, showing frontal sinuses mapped out by illumination. There is marked asymmetry, the septum lying altogether to the right.

[*To face page* **125.**

actually thicker when measured, may transmit light more readily and with greater intensity than thinner and denser bone. A number of observations leads me to conclude that, as a rule, bone which is three mm. or less in thickness illuminates brightly, though exceptions to this are met with, as for example in one case in which bone only two and three mm. thick failed to transmit any light, owing to its great density. Again, where the bone measured four mm. and more, one found that no illumination took place, though four or five exceptions occurred in which, from the porosity of bone five and six mm. thick, an illuminated area was mapped out upon the skull. A difference in the intensity of the illumination of the two sinuses in the same skull was noted in a fair proportion of cases. The illuminating capabilities of the sinuses appear to vary in different races, a point which will be discussed in greater detail when we consider the causes of non-illumination of the cavities.

As a rule, the intensity of the illuminated area is more marked in the female than in the male skulls, a result to be expected where the bones are thinner. There are, however, a number of female skulls in which very faint illumination is obtained, and others in which the sinuses entirely fail to illuminate.

Occasionally the area of illumination slightly exceeds, by 2 or 3 mm. at the most, the sinus through which the rays have passed. This is apparently due to the porous character of the bone immediately beyond the limit of the sinus, the diploë between the two tables of the frontal bone being large, and thus offering little opposition to the further passage of the luminous rays. An example of this is seen in Fig. 1, Plate XI., where the right frontal sinus is rather smaller than the illuminated area indicated by the black line would have led us to suppose.

In 13 of the sinuses which were illuminated and then

opened, the cavity was found to be larger than the area of illumination appeared to indicate. This result is due to the fact that the rays did not pass through the whole of the anterior wall of the sinus. The bone towards the outer angle of the cavity, just above the supra-orbital margin, and formed by the outer end of the supraciliary ridge, is often thick, and offers resistance to the light.

The frontal sinus may entirely fail to illuminate. This may occur on one or upon both sides of the skull. As this phenomenon has so important a bearing upon the clinical value of transillumination, we must study it in somewhat greater detail. The cause of failure is mainly due to the thickness of the bony walls of the sinus. This does not, however, always result from the presence of well-marked supraciliary ridges. While it is true that the majority of skulls which do not illuminate have well-marked supraciliary ridges, there are many sinuses with only faintly-marked ridges negative to illumination. As we have already indicated in our reference to the variations in the intensity of the illuminated area, the denser character of the bone in some cases interferes with the passage of the rays. There is, however, another but less frequent cause which interferes with the illumination of the sinus. In two instances in which illumination was negative, and in which the anterior wall of the sinus was subsequently removed, it was found that the cavity was so shallow that the rays of the lamp, instead of passing through its floor, fell behind it, and did not enter the sinus at all.

Out of 560 skulls which we have illuminated, there were 402 in which both frontal sinuses were present. Of these latter, both cavities illuminated in 223 skulls, neither sinus illuminated in 119 skulls, while in 60 the sinus on one side failed to illuminate. Again, we must remember that in a number of skulls one or both sinuses are absent, and that when

there is no sinus present, no area of illumination is obtained. Thus, out of the 560 skulls just referred to, 85 had no frontal sinuses, while in 73 the cavity was absent upon one side. Hence we have a large number of skulls in which the sinuses are absent, sometimes on both sides, sometimes only on one side, but in every case negative to illumination. An examination of the 73 skulls in which one sinus was absent, and therefore negative to illumination, reveals this fact too, that the sinus on the opposite side may or may not illuminate. Thus in 42 of these skulls the single sinus present did illuminate, while in the remaining 31 skulls it did not do so.

In connection with these anatomical points, it is necessary to draw attention to the fact that the skulls of the aboriginal Australians, of the Maoris of New Zealand, and the Esquimaux, are included in the statistics. In these races, as we have seen, there is a larger percentage of skulls without sinuses, and a greater number of sinuses with thick bony walls, than in the more civilised races. Consequently, by their inclusion the number of skulls which show no area of illumination is increased. In the races above mentioned the clinical aspect of illumination hardly enters into consideration. If, however, the European crania be studied by themselves, in connection with this point, we find a certain proportion of the skulls without one or both sinuses, a number in which the sinuses fail to illuminate, and others in which the intensity of the illumination upon the two sides of the same skull is unequal.

Amongst 240 European crania, 41, or 17 per cent., had one or both frontal sinuses absent. Out of 124 Scottish crania, 85 sinuses failed to illuminate, sometimes on one side, sometimes upon both sides. In 16 English crania, 4 sinuses; in 20 Irish crania, 19 sinuses; in 37 French crania, 14 sinuses; in 13 German crania, 3 sinuses; in 7 Swiss crania, 5 sinuses; and in 8 Russian crania, 4 sinuses failed to illuminate. It is evident,

therefore, that even among the European peoples the failure of a sinus to illuminate is a factor which must be taken into consideration.

Results obtained from Illumination of the Frontal Sinuses in Cadavera.—In order to estimate the value of illumination in living persons, it is necessary to ascertain if the soft parts covering the bones have any influence upon the transmission of the rays of light. For this purpose, the examination of cadavera is of service. Through the kindness of my friend Dr. Harvey Littlejohn, I was able to make some observations upon this point. The sinuses were first illuminated in the ordinary way, and the bright area thus obtained was mapped out upon the skin by means of nails, which were made to penetrate the periosteum and underlying bone. After the scalp and periosteum had been reflected downwards sufficiently far to allow of the lamp being placed directly against the bony floor of the sinus, the bare bones were next illuminated and the area mapped out. The sinuses were then opened, and the results of illumination were compared with the dimensions of the cavities. Although these observations were limited in number, they furnished sufficient proof of the fact that the sinuses could be defined by illumination through the soft parts. The chief effect produced by the overlying soft tissues is apparently to diminish the intensity of the light that is transmitted.

Results obtained from the Illumination of the Frontal Sinuses in healthy living Persons.—While a large number of presumably healthy persons were illuminated for the purpose of ascertaining whether results similar to those found in the skulls could be obtained, notes of the following 35 may be thus summarised. Of these, the sinuses illuminated upon both sides in 18 persons with equal intensity; 15 of the cases were males and three were females. Again, seven illuminated on both sides, but there was a difference in the intensity of the

illumination in the two sinuses; all those cases were males. Of the remainder, the sinuses in six persons—four males and two females—failed to illuminate on either side, while four—all males—illuminated upon one side, but not upon the other. These results, therefore, were very similar to those already described in connection with the illumination of the skulls. It was of course impossible to conclude whether the absence of an illuminated area indicated the absence of a sinus, or merely considerable thickness of the bony walls of the cavity.

Results obtained from the Illumination of the Frontal Sinus in Cases of Chronic Suppuration.—In considering the clinical aspect of transillumination of the frontal sinuses, we must seek, as in the case of the maxillary antra, for a comparison of the results obtained upon the two sides of the skull. An examination of thirteen patients, in whom the exact condition of the sinus was proved by operative interference, furnishes the following results. In three of the patients the diseased sinuses did not illuminate. As in two of them, however, both cavities were affected, no information could be obtained from a comparison of the two sides. In the third the opposite healthy sinus illuminated faintly, so that there was an obvious contrast. In the remaining patients, in eight of whom the affection was unilateral and in two bilateral, the diseased sinuses illuminated. Of the eight cases of unilateral disease, in four the affected sinus illuminated with the same intensity as the healthy cavity upon the opposite side, while in the remaining four the illumination was not quite so brilliant as upon the healthy side. In nearly all these cases the test was repeated upon more than one occasion, and usually upon the day preceding the operation In addition to the thickened and frequently polypoid condition of the mucous membrane lining the cavities, pus was also present in many of the sinuses, and welled out when the mucous membrane was incised.

It does not appear as if the sex of the patients in any way influenced the results obtained in these cases. Six of the patients were males and seven were females. Of the three that were negative to illumination, two were women. Knowing that the sinuses in the female skulls usually show a greater intensity of illumination than those in the male, we would have expected absence of illumination more frequently amongst the latter.

Although these observations are not based upon a large number of cases, they nevertheless clearly demonstrate the fact that a considerable proportion of frontal sinuses in which there is chronic suppuration, illuminate. Indeed, we are justified in maintaining the view that it is the exception rather than the rule to find opacity of the affected sinus. This experience apparently differs from that of some other observers. Thus, Lubet-Barbon and Furet[1] of Paris apparently attach importance to the illumination test in diagnosis. They record more than one instance in which the diseased frontal sinus failed to illuminate, and thus contrasted with the illumination upon the opposite healthy side. It is interesting, however, to note that in one of their cases of suspected frontal sinus mischief, in which the cavity was opaque, that phenomenon resulted from anatomical causes. When the sinus was opened, it was found to be perfectly healthy, but of small size and surrounded by thick bony walls. In a case which I was asked by Mr. Robert Purves to illuminate two or three years ago, and in which the patient's symptoms pointed to frontal sinus mischief, I found complete opacity on both sides, and advised the surgeon to make an exploratory opening. No sinus was found, but it was satisfactory to learn that the patient was completely relieved of the pain which had formed one of the most prominent features in her case. In the light of our present knowledge, we should

[1] *Loc. cit.*

suspect some anatomical condition to be the cause of the opacity, when neither sinus illuminates in a case presenting only unilateral signs of disease.

Moure[1] of Bordeaux, in dividing the signs of suppuration of the frontal sinus into two groups, namely, those which make the diagnosis probable and those which render it certain, places opacity of the suspected sinus in contradistinction to illumination of the opposite side in the latter group. Amongst other observers, however, there is some difference of opinion with regard to the diagnostic usefulness of the test.

Conclusions regarding Transillumination in Chronic Suppuration of the Frontal Sinus.—With the knowledge derived from the study of illumination of the frontal sinuses, both in healthy and diseased conditions, we are forced to the conclusion that the test is of little or no practical value in the diagnosis of cases of chronic suppuration in these cavities. This opinion is arrived at on the following grounds :—

1. One or both sinuses may be absent, and when this anatomical condition exists, there is opacity on one or both sides of the skull.

2. A certain proportion of healthy sinuses fail to illuminate ; this may occur on one or on both sides of the skull.

3. A sinus on one side of the skull may illuminate with less brilliancy than its fellow, although both are perfectly normal.

4. Many sinuses containing pus, and with their mucous membrane thickened and often polypoid, illuminate with considerable intensity.

When there is absence of illumination, therefore, we must always feel some doubt as to whether it is due to the absence of the sinus, to a thick-walled sinus, or to a diseased condition of the cavity.

[1] *Journ. Laryngol.*, London, September, 1899.

Although minimising the value of illumination, I do not wish it to be inferred that the method should be altogether discarded in these cases. On the contrary, it should always be employed. When the question of operative interference is under discussion, the surgeon will find a preliminary illumination of the sinus of considerable value. In cases of suspected suppuration, it is preferable, I think, to find that the cavity illuminates. A diagnosis can be arrived at in the majority of cases by less uncertain means, while illumination dispels any doubt as to the existence or non-existence of the sinus. The dimensions of the cavity can by this means be mapped out and the position of the septum ascertained, both of these points being of undoubted value when the question of an external operation is under consideration.

III. Transillumination of the Ethmoid Cells

Attempts have from time to time been made to give illumination a place in the diagnosis of suppuration in the ethmoidal cells, and observations were apparently first made by Robertson[1] and Ruault[2] with this end in view. The results have not proved very satisfactory, and the test is not regarded as one of any importance in the diagnosis of this affection. The part of the face to which Ruault directed attention was the bridge of the nose. When the lamp is placed in the mouth, the nasal bones may become illuminated, the rays having first passed through the hard palate and the nasal chambers. I have examined a number of healthy persons with the object of testing the illumination of the nasal bones. So much variation, however, was met with that it is practically impossible to formulate any rules for guidance. In many cases these bones failed to illuminate on either side; in others,

[1] *Journ. Laryngol.*, London, 1892. [2] *Arch. de Laryngol.*, Jan. and Feb. 1893.

the illumination was confined to one bone, or the nasal bone illuminated more faintly and less extensively upon one side than upon the other; while in other cases, again, both the intensity and the distribution of the light corresponded upon the two sides.

IV. Transillumination of the Sphenoidal Sinus

The anatomical position of this sinus does not permit of its investigation by this method.

CHAPTER VIII

THE ETIOLOGY AND PATHOLOGY OF SUPPURATION IN THE ACCESSORY SINUSES

A. Etiology.

Inflammation and suppuration in the nasal sinuses may arise in the course of certain acute affections, such as influenza, pneumonia, scarlet fever, measles, typhoid fever, diphtheria, smallpox, and cerebro-spinal meningitis. The inflammation may reach the sinus by direct extension from the nose, fauces, and naso-pharynx, or the cavities may become involved through the blood-stream in the course of a general systemic infection. E. Fränkel's[1] investigations have shown the frequency of sinus complications in croupous pneumonia, while the great importance of influenza as a causative factor has now been demonstrated beyond all dispute. There is no doubt that an actual increase in the number of cases of purulent sinus disease is due to the greater frequency and prevalence of the influenza epidemics. In the epidemic of 1890, Weichselbaum[2] found suppuration present in a large number of post-mortem examinations upon influenza patients, while Garel[3] has given us a clinical record of a series of cases of acute inflammation of the maxillary and frontal sinuses which occurred during the epidemic of 1899–1900. In cases of acute coryza, in which

[1] *Virchow's Archiv*, 1896, Bd. cxliii. [2] *Wien. med. Wochenschr.*, 1890, S. 223.
[3] *Rev. hebd. de laryngol.*, Bordeaux, June 9, 1890.

there has been no reason to suspect an influenzal infection, sinus inflammation may complicate the "cold." Suppuration has also been ascribed by Weichselbaum to an attack of facial erysipelas: it is more reasonable, however, when these conditions are associated, to regard the erysipelas as secondary to the nasal discharge. Passing from these acute conditions, we find that suppuration in the sinuses is sometimes associated with such chronic affections of the nose as syphilitic ulceration, benign and malignant growths. Tuberculous disease of the accessory cavities appears to be rare, although Neumayer[1] and Réthi[2] have recorded two or three cases in which tubercle of the maxillary sinus occurred in association with, but secondary to, tubercle of the gums and nasal mucous membrane. Lapalle,[3] who examined the sinuses in 59 cadavera in which death was due to pulmonary or meningeal tuberculosis, found sinus disease in 19 instances, but no facts are furnished indicating that the latter condition was tuberculous. The relation of ozæna to accessory cavity suppuration is still a vexed question: in a certain number of cases the two conditions are associated, but the relation of cause and effect is still debated. Suppuration has been ascribed to nasal polypi, but in the majority of cases in which these conditions co-exist, the latter are of secondary origin, and result from the constant irritation to which the mucous membrane is subjected from the flow of pus over it. In the case of the antrum, dental caries is an important etiological factor, though even on this point all are not agreed as to the relative frequency of a dental or nasal origin in antral suppuration.

Inflammation may be due to trauma, consequent upon fractures of the sinus walls. It may also follow such opera-

[1] *Arch. f. Laryngol.*, Berlin, Bd. ii.
[2] *Wien. med. Presse*, 1893, No. 19, 1899, No. 51.
[3] *Arch. internat. de laryngol.*, May and June, 1899.

tions upon the nasal chambers as the removal of polypi and the injudicious and prolonged insertion into the nose of cotton-wool or gauze plugs, *e.g.* in controlling epistaxis. Further, the extraction of teeth and the resection of the superior maxillary division of the fifth cranial nerve, as reported by Langenbeck, have set up inflammatory mischief in the antrum. It is very important to remember, too, that the pus from one sinus may infect another. The intimate anatomical relations between the various ostia sufficiently indicate how this may arise, while the non-recognition of this fact may lead to failure in treatment. The possibility of infecting the anterior ethmoidal cells or frontal sinus from too forcible syringing of the antral cavity must also be borne in mind.

B. Bacteriology.

The bacteriology of accessory sinus inflammation has been studied both in the living subject and upon the cadaver, and a number of organisms have been described in connection with it. We are mainly indebted to the work of Weichselbaum and E. Fränkel for our knowledge of this subject, although a number of workers have recently turned their attention to the same field. Amongst the various organisms may be mentioned the *Diplococcus pneumoniæ* (Fränkel's *pneumococcus*), the *pneumobacillus* of Friedländer, the *Bacterium coli*, and a number of pyogenic organisms, varieties of *streptococci* and *staphylococci*. The influenza bacillus has been demonstrated by Lindenthal,[1] Howard and Ingersoll,[2] and Moszkowski.[3] An interesting case has recently been recorded by Luc,[4] in which the pneumococcus alone was found in acute inflammation of the frontal and

[1] *Wien. klin. Wochenschr.*, 1897, No. 15.
[2] *Am. Journ. Med. Sc.*, Phila., 1898, vol. cxv.
[3] *Arch. f. Laryngol.*, Berlin, 1900, Bd. x. Heft 2.
[4] *Rev. hebd. de laryngol.*, Bordeaux, July 15, 1899.

maxillary sinuses. The patient was infected while conducting a post-mortem examination upon a case of cerebro-spinal meningitis, from which the pneumococcus was cultivated. Howard and Ingersoll failed to find the tubercle bacillus in a number of cases of chronic suppuration examined with that object in view. True diphtheritic membrane has been found in the antrum by Weichselbaum,[1] E. Fränkel, Dmochowski,[2] and Pearce.[3] The last-named investigator has made some very interesting post-mortem observations upon a number of cases of uncomplicated diphtheria, and of diphtheria associated with measles or with scarlet fever. In considerably more than half of the unmixed cases of diphtheria, inflammatory changes were found in the antra, and the Klebs-Löffler bacillus was present in all but three. In three of the four cases complicated with scarlet fever, the antra contained pus in which streptococci and staphylococci were found. These observations, however, refer only to fatal cases. Some interesting points worthy of more extended research have lately been published by Stanculeanu and Baup.[4] These observers have divided sinus suppurations into two groups,—those primarily due to dental caries, in which the organisms found were mainly anaërobic, *e.g. B. ramosus, perfringens, serpens,* etc., and those of nasal origin, in which the organisms were chiefly aërobic, *e.g. pneumococci, streptococci, staphylococci.* In the former the pus was fœtid, in the latter non-fœtid.

C. Pathology.

Inflammation of the accessory nasal sinuses may be acute or chronic, and be induced by those organisms to which we have already referred. It is characterised by such changes as

[1] *Wien. med. Jahrb.*, 1881. [2] *Arch. f. Laryngol.*, Berlin, 1895, Bd. iii.
[3] *Journ. Bost. Soc. Med. Sc.*, March, 1899.
[4] *Arch. d. Sc. Med.*, Paris, May–July, 1900.

are usually associated with inflammation of mucous membranes. These vary with the severity of the infection, and are modified according to the patency or occlusion of the orifice of the cavity. In acute inflammation the mucosa becomes congested, infiltrated with round cells, and swollen, while a serous exudation is poured out, constituting an acute catarrh of the membrane. This exudation may become sero-purulent or purulent, and if mixed with a quantity of mucus it presents a muco-purulent character. If the ostium of the sinus becomes blocked by the swollen mucous membrane, the exudation is retained under tension, and the clinical symptoms and signs become aggravated. Distension of the bony wall of the cavity where there is least resistance may occur, and in some cases be followed by perforation and the formation of a fistula and its sequelæ. Spontaneous cure may result; on the other hand, the inflammatory process may become chronic. In many cases the affection is not recognised clinically until this stage is reached. When a chronic suppuration exists, various secondary changes are met with in the mucous membrane. The round cell infiltration already referred to may be followed by the formation of new fibrous tissue, causing thickening of the membrane. The mucous glands are to a large extent destroyed, while cysts, varying considerably in size, are formed by dilatation of the gland ducts, or even of the acini themselves. The mucous membrane frequently presents a uniformly swollen gelatinous appearance. Not infrequently this condition is associated with the presence of numerous soft polypoid-like processes, which vary considerably in size and in number, and which may even fill up the interior of the cavity. Occasionally a single polypus is met with in the sinus. In the case figured on Plate XXXIX. Fig. 1, a single fairly large polypus is seen attached to the posterior wall of the maxillary sinus: it measures one inch in length and has a base of attachment measuring about half an inch: the

PLATE XXXIX.

FIG. 1.—From the Anatomical Museum of the University of Edinburgh. Right maxillary antrum opened into from behind. A single mucous polypus is seen attached to the wall of the cavity.

FIG. 2.—From the Anatomical Museum of the University of Edinburgh. The outer wall of the right nasal chamber. A number of small polypi are growing from the mucous membrane covering the uncinate process and adjacent portion of the middle meatus.

[To face page 138.

mucous membrane covering the uncinate process is considerably thickened. In consequence of the swollen œdematous condition of the lining membrane, the ostium of the cavity may become partially blocked, and the free drainage of pus interfered with. The deeper periosteal layer also becomes involved, leading either to a plastic or a destructive process in the subjacent bone. While caries of the osseous wall is met with, and sometimes necrosis, it is undoubtedly the fact that in a very large number of cases no destruction of bone occurs, which is probably accounted for by the fact that the bony walls of these cavities are provided with a periosteal covering on each aspect.

In consequence of destruction of the bone, perforation of the sinus wall may result and various complications follow. A communication may thus be established between the antrum and ethmoidal cells, or between these cells and the frontal sinus. In a similar way, the frontal sinus, ethmoidal cells, and antrum may communicate with the orbital fossa, and fistulous tracks result therefrom. Implication of the orbit and the formation of a secondary abscess in that cavity may lead to temporary or permanent injury of the eyeball and its adnexa, and may prove the starting-point of intracranial complications. Orbital cellulitis, with abscess formation, may occur without any perforation of the bone, infection taking place through the blood or lymph channels. Within the nose itself alterations in the mucous membrane are frequently observed. These consist in the development of polypi in the middle meatus and its vicinity. They may completely block the nasal chamber or be insignificant in size. The nasal lining membrane generally presents a swollen and reddened appearance, while the inferior turbinated body may be turgescent; these intranasal changes probably result from the irritation of the purulent nasal discharge. On Plate XXXIX. Fig. 2, polypi

are seen growing from the uncinate process and occupying the anterior part of the nasal chamber, while a single polypus is attached posteriorly to the middle turbinated body. Post-mortem examinations have been made by E. Fränkel,[1] Harke,[2] Kiaer,[3] Lapalle[4] and Wertheim[5] upon the accessory sinuses in individuals dying from various causes, with the object of ascertaining the frequency of suppuration in these cavities at the time of death. Of the more recent observations, we find that in 195 post-mortem examinations made upon adults by Kiaer, pus was found in 88 cases. The maxillary sinus was most frequently affected, then the sphenoidal sinus, ethmoidal cells, and frontal sinus in that order. Lapalle's observations, based upon 169 autopsies, show affection of the sinuses in 55 cases. With regard to the relative frequency with which suppuration occurred in the different cavities, we find that Lapalle's figures correspond to those of Kiaer, the antrum coming first and the sphenoidal sinus second upon the list. The frequent occurrence of disease in these sinuses at the time of death is striking; if the affection has not arisen in connection with the fatal illness of the patient, it suggests that many individuals go about during life with some affection of these cavities. Another interesting point is the occurrence of so many cases of suppuration in the sphenoidal sinus, 29 recorded by Kiaer and 19 by Lapalle, thus placing that sinus second on the list. If the condition does not arise during the fatal illness, it is probable that many cases of disease in the sphenoidal sinus must be overlooked during life. Clinical experience places inflammation of the frontal sinus in a much more prominent position than the figures quoted here indicate.

[1] *Loc. cit.* [2] *Beitr. z. Path. u. Therap. der ober. Athmungswege*, Wiesbaden, 1895.
[3] *The Laryngoscope*, St. Louis, February 1899.
[4] *Loc. cit.* [5] *Arch. f. Laryngol.*, Berlin, 1900, Bd. xi.

PLATE XL.

Portion of skull from the Anatomical Museum of the University of Edinburgh. There is great dilatation of the air cell in the right middle turbinated bone. The septum nasi is deviated to the left. There is no clinical history attached to this specimen.

[*To face page* 140.

The question of associated sinus suppuration is of great importance. A few statistics may be quoted to show the relative frequency with which it occurs. While disease of the maxillary sinus not only occurs most frequently, but is also found more often by itself, the combination of frontal, maxillary and ethmoidal suppuration is by no means of infrequent occurrence. Of the 13 cases of frontal suppuration reported by Kiaer, the maxillary sinus of the same side was affected in seven, while in five cases of disease of the frontal sinus referred to by Lapalle, the antrum was similarly affected in three. In eight cases of suppuration in the frontal sinus operated on by Jansen,[1] the ethmoidal cells were similarly affected. Milligan,[2] in 15 cases of frontal sinus disease, of which 13 were unilateral and two bilateral, found one or more of the other sinuses affected in all save one. The maxillary sinus was involved in no fewer than nine instances, while in 11 of the cases there was associated ethmoidal suppuration. Herbert Tilley,[3] in a list of 14 cases of suppuration in the frontal sinus, of which seven were unilateral and seven bilateral, found the maxillary antrum affected in nine, and the ethmoidal cells in one. In two of the cases of bilateral frontal affection the antra on both sides were also diseased. In six cases of frontal suppuration reported by Walker Downie,[4] five had ethmoidal disease; while Lubet-Barbon and Furet,[5] in 11 cases of frontal suppuration, never found the disease confined to these cavities alone. Grünwald[6] treated 34 patients with suppuration in the sphenoidal sinus, in all 45 sinuses being diseased, and in only nine was that cavity affected by itself. This list might be considerably enlarged, but it sufficiently illustrates the frequency of associated sinus disease. In six cases of chronic suppuration of the frontal

[1] *Arch. f. Laryngol.*, Berlin, 1893, Bd. i. Heft 2.
[2] *Lancet*, London, February 19, 1898.
[3] *Ibid.*, London, July 14, 1900.
[4] *Glasgow Med. Journ.*, May, 1899.
[5] *Loc. cit.*
[6] *Loc. cit.*

sinus coming under my own care, five were unilateral and one bilateral; in the five cases of unilateral disease the corresponding maxillary antrum was also affected, and in one of them the ethmoidal cells of the same side and the maxillary antrum upon the opposite side. In the case of bilateral disease the ethmoidal cells on both sides were similarly affected.

Intracranial complications may be secondary to suppuration in any of the accessory sinuses, though not so often in connection with antral disease. Although more frequently due to chronic affections, their occurrence in acute cases must not be lost sight of. The infection occurs as the result of caries and destruction of the sinus wall, thus establishing a direct communication with the cranial cavity, or it may spread inwards through the venous channels or lymphatic vessels of the diploë, without any macroscopic evidence of the path of infection. In some cases the mischief passes from the orbit along the ophthalmic veins to the cavernous sinus. Perforation of the posterior wall of the frontal sinus, or of the roof of the sphenoidal sinus, may be followed by extradural, subdural, or cerebral abscess, by purulent basal or general meningitis, by thrombosis of the cavernous, petrosal, or superior longitudinal sinuses, or by a combination of two or more of these complications. An ever-increasing number of fatal cases is being recorded, and in many of these instances the real cause of the intracranial complication has only been revealed at the post-mortem examination. This subject has been studied with considerable care and completeness by Dreyfuss,[1] and since the publication of his monograph in 1896 numerous observations have been made by various writers.

[1] "Die Krankheiten des Gehirns," Jena, 1896.

CHAPTER IX

THE DIAGNOSIS OF SUPPURATION IN THE ACCESSORY SINUSES

I. The Diagnosis of Acute Inflammation in the Accessory Sinuses

Acute inflammation and suppuration of one or more of these cavities probably occur more frequently as concomitant complications of acute coryza, influenza, and certain of the exanthemata than is generally supposed to be the case. The onset of the inflammation may be masked by the severity of the coryza which precedes or accompanies it. Sometimes the patient's attention is drawn to the fact that during the acute stage of the cold the muco-purulent discharge is more than usually copious, perhaps especially so from one nostril, and, further, that it continues for a longer time than is customary. The symptoms commonly associated with acute inflammation in the accessory cavities are considerably modified according as the ostium of the cavity remains patent, or becomes closed from swelling of its mucous membrane. In the former case the secretion drains away more or less freely, and a spontaneous cure frequently results ; while in the latter case there is retention, and consequent aggravation of the symptoms.

(*a*) **The Maxillary Sinus.**—The symptoms of an acute coryza may be aggravated by severe neuralgia in the cheek and forehead of the affected side, the pain in some of these cases

being associated with a considerable degree of photophobia. A rigor followed by rise of temperature sometimes precedes the onset of the pain, and tenderness may be elicited upon pressure over the cheek or upon the gums. The severity of the symptoms may then be greatly diminished by a sudden and copious flow of secretion from the corresponding nostril. The discharge varies in character, being perhaps at first serous or slightly blood-stained, but becoming muco-purulent or purulent; from the first it may consist entirely of thick creamy pus. Cessation of the flow of pus may be followed by an exacerbation of the symptoms, again to be relieved by a sudden return of the discharge. This alternation in the character of the symptoms is very suggestive of the condition. The discharge gradually diminishes in quantity, with a corresponding amelioration of the pain and local discomfort, and after a varying period of time either a spontaneous cure results or the condition becomes chronic. Orbital complications seldom arise in connection with acute antral suppuration; they are evidenced by severe pain in the eye, displacement of the globe, and the formation of pus in the surrounding cellular tissue.

If the nose be examined by anterior rhinoscopy in a case of this kind, the mucous lining on the affected side is probably found red and swollen, and the inferior turbinated body turgescent. Inspection of the middle meatus may reveal a drop of pus in that situation, increasing in quantity after the head has been inclined forwards. Transillumination is of considerable diagnostic value: if opacity of the cheek and absence of the subjective light sensation in the eye of the affected side exist in conjunction with the symptoms and signs enumerated, the diagnosis of antral suppuration is almost certain. It may be necessary to differentiate between suppuration in the antrum and an acute periostitis of the upper jaw. In the latter condition, swelling over the facial wall of the

sinus and the absence of those intra-nasal signs just described will assist the surgeon in his diagnosis. Should the ostium maxillare be blocked in antral suppuration, a differential diagnosis might prove somewhat more uncertain, and necessitate an exploratory puncture.

The following case, seen in consultation with Mr. Dowden, illustrates an acute affection of the maxillary sinus :—

The patient, who had previously been enjoying good health, was seized with symptoms suggesting an attack of influenza. Two or three days later she began to have pain in the left cheek, and complained of some stuffiness in the left side of the nose. These symptoms became aggravated, the pain becoming very severe at times, especially at night, and causing sleeplessness and considerable discomfort. The temperature rose to 100° F., but was apparently never above that point. Occasionally there was a slight discharge of mucus from the left nostril, but its evacuation gave the patient no permanent relief. Examination of the left nasal chamber showed the mucous membrane to be inflamed, and the inferior turbinated body turgescent. In the middle meatus a small drop of pus was visible. Illumination revealed complete opacity of the left cheek, and an absence of any light sensation in the left eye. Both these signs contrasted markedly with what was observed upon the opposite side. These facts afforded sufficient data for concluding that the left maxillary antrum contained pus. On opening the cavity, a quantity of purulent discharge escaped, and the patient's symptoms were relieved.

Schmiegelow,[1] Röpke,[2] and others have reported a few cases of acute inflammation of the superior maxillary bone occurring in infants a few weeks after birth. The symptoms thus presented are severe. The onset of the illness is sudden, and is ushered in with fever, accompanied by redness and swelling of the cheek and eyelids, followed by discharge of pus into the nose and mouth or on to the face through one or more openings. Necrosis of part, or even of the whole, of the upper jaw may occur, numerous small sequestra becoming detached. These cases present the signs of acute osteo-myelitis of the upper jawbone, as Schmiegelow first pointed out, a condition which some

[1] *Arch. f. Laryngol.*, Berlin, Bd. v. Festschrift. [2] *Arch. Otol.*, N. Y., August, 1899.

writers, however, have described as acute suppuration in the antrum. Neither on anatomical nor on clinical grounds can this latter diagnosis be regarded as correct.

(*b*) **The Frontal Sinus.**—Acute inflammation of the lining membrane of this cavity is ushered in by symptoms which closely resemble those described in connection with the antrum. Fever and general malaise are accompanied by intense frontal headache and a feeling of weight and oppression above the eye, and sometimes a sensation of fulness behind it. Percussion immediately above the inner third of the supra-orbital margin on the suspected side elicits tenderness, a symptom, however, which is rendered much more acute when the floor of the sinus is pressed upon. Redness and swelling of the skin over the cavity, along with slight œdema of the upper eyelid, may afford further evidence of some deep-seated affection. In the absence of external signs, or when the patient is seen before there has been any nasal discharge, the case may easily be mistaken for one of severe neuralgia. A sudden discharge of pus into the nose is followed by abatement of the symptoms, and the patient feels better. Anterior rhinoscopy may reveal a condition very similar to what is seen when the antrum is affected. Some observers obtain considerable assistance in acute cases from transillumination of the frontal sinus, finding the affected cavity opaque or considerably darker than that on the opposite side. If, in conjunction with these phenomena, the maxillary sinuses illuminate, the diagnosis of frontal sinus suppuration is still further established.

The above symptoms are illustrated in the case of G. B., æt. 39, who came to the dispensary with the following history. Five weeks before, he had suffered from influenza, from which he had apparently recovered without any complications. Five days before his visit to the dispensary he had been seized with intense frontal headache, which prevented sleep. On the following day a slight purulent discharge was noticed to come from the right nostril, and the pain was somewhat relieved. During the next few days

severe paroxysms of pain alternated with a somewhat sudden discharge from the nose, the pain being then entirely relieved. While the patient sat in the waiting-room prior to his examination, a severe attack of pain supervened.

On examination of the nose, the right inferior turbinated body was seen to be engorged, and the anterior end of the right middle turbinated was red and swollen. There was no pus in the middle meatus, and Fränkel's posture test was negative. There was great tenderness on percussion and upon pressure over the anterior wall of the right sinus, while the patient would hardly permit the floor of the sinus to be touched. A probe was passed upwards towards the frontal sinus, but it was doubtful if the cavity was reached. Both maxillary sinuses illuminated, the right being less brilliant than the left. The same phenomena were seen on illumination of the frontal cavities. Shortly after the examination there was a sudden flow of pus into the right nasal chamber. A diagnosis of suppuration in the right frontal sinus was made, and the patient was admitted into the Deaconess Hospital. Improvement commenced; the attacks of pain diminished in intensity and frequency, and the discharge became less profuse; at the end of seven weeks all symptoms had disappeared, no operative interference being required.

Should the ostium frontale become blocked, a more serious train of symptoms may supervene. As the thin bony floor of the sinus offers least resistance, expansion of this wall follows most readily with the formation of a fluctuating swelling in the upper and inner angle of the orbit. Exophthalmos, and a downward and outward displacement of the eyeball, along with certain visual disturbances, may follow distension of the cavity. Cases have occurred in which rupture of the bony wall has taken place with the formation of an orbital abscess. Perforation of the posterior sinus wall, followed by intracranial mischief, is a rare complication in acute cases.

(*c*) **The Ethmoid Cells.**—Acute suppuration, whether occurring in the ethmoid labyrinth or limited to the cell of the ethmoidal bulla or of the middle turbinated bone, is not frequently met with. Grünwald[1] reports two cases in which a limited suppuration of this kind occurred. Both patients

[1] *Loc. cit.*

suffered from headache and severe pains in the forehead, and complained of nasal discharge, which in one of the cases was for some days of a watery nature, afterwards becoming purulent. Examination of the nose showed the mucous membrane to be red and slightly swollen, and pus was visible upon the middle turbinated body. Irrigation of the nose and the establishment of a free exit for the pus permanently removed the symptoms. Jeaffreson[1] reports an acute case with sudden onset occurring during convalescence from scarlet fever. The patient was seized with rigors, fever, headache, and cerebral symptoms. In a few days there was exophthalmos of the right eye, with defective vision and double optic neuritis. An incision made on the inner side of each orbital cavity evacuated pus. The abscesses were found to communicate. In twenty-four hours all acute symptoms disappeared.

(*d*) **The Sphenoidal Sinus.**—Acute inflammation of this cavity has not been very frequently recognised clinically: several cases, however, have been described by Schäffer.[2] The symptoms resembled those of an aggravated nasal and nasopharyngeal catarrh, the patient complaining of intense headache in the occipital region and on the vertex of the skull. Accompanying this were symptoms of sleeplessness and general malaise, and the temperature rose above that usually met with in an ordinary cold. In some cases giddiness was a prominent symptom. If an objective examination should be made in the acute stage, the mucous membrane in the posterior part of the nose will be found red and turgescent, the olfactory slit between the middle turbinated and the septum being narrowed by the swollen condition of the mucosa. Mucopurulent and purulent secretion may be also visible, both by anterior and posterior rhinoscopy, but there are no crusts such as occur in the chronic form of the affection.

[1] *Lancet*, London, July 20, 1890. [2] *Deutsche med. Wochenschr.*, Leipzig, No. 47, 1892.

II. The Diagnosis of Chronic Suppuration in the Accessory Sinuses, or so-called "Latent Empyema"

(1) General Symptomatology

A brief résumé of certain symptoms and signs which should suggest the possible existence of chronic suppuration in one or more of these cavities, must in the first place be considered. It is of primary importance, however, to bear in mind the fact that pus may be secreted for months, and even years, in one of the accessory sinuses, with almost entire absence of pain or swelling to suggest the existence of such an inflammatory condition. The term "latent empyema" has in consequence been applied to this affection. On the other hand, a more general recognition of the fact that a purulent nasal discharge, with or without some degree of nasal obstruction,—especially if the discharge is unilateral,—may be due to sinus mischief, has led to a more systematic and successful examination of these air-spaces. In complicated cases in which more than one sinus is affected, a correct and complete diagnosis is by no means easy, and careful and repeated observation becomes necessary before a knowledge of the exact condition is ascertained. Even when only one sinus is diseased, diagnosis is sometimes difficult.

(*a*) *Nasal Discharge.*—This may be the chief, or perhaps the only symptom complained of. It is often difficult to ascertain the date or manner of its origin. The patient may complain that he has a "chronic cold" which has lasted for many months, or even years. The discharge varies in character. In some cases it is mainly purulent, being of a thick creamy consistence, and yellow in colour. In others, again, it is thinner and more stringy, owing to a considerable admixture of mucus; and sometimes the mucus predominates, rendering

the secretion clear, but of a tenacious consistence. Killian[1] has laid stress, in diagnosis, upon the green colour of the pus from the frontal sinus; but too much diagnostic importance must not be attached to any of the physical characters of the nasal discharge. The patient may complain that at times he both expectorates and removes with the aid of his handkerchief small crusts; there is a greater tendency for the discharge to dry into crusts in sphenoidal sinus disease, and, according to Hajek, the same thing is noticed in ethmoid cell suppuration. He may complain, too, of a fœtid odour, and that the discharge which passes into the throat has a bad taste. In one of my cases the patient was able to distinguish the fœtor in one nostril. When a bad odour alone is complained of, a suspicion of a possible maxillary sinus suppuration should be aroused, as occasionally that constitutes the only subjective symptom met with. In some cases even of long-standing antral suppuration, the discharge is not fœtid. As a diagnostic aid, it is important to bear in mind that in sinus disease the sufferer is conscious of the odour, while his neighbours are not; in fœtid atrophic rhinitis, on the other hand, the opposite is usually the case, the sense of smell being, as a rule, destroyed in the latter affection. The two conditions, however, sometimes co-exist; further, in sinus suppuration the nose may be so blocked with polypi that the sense of smell is lost.

The discharge may be unilateral or bilateral: its presence in both nasal chambers does not necessarily imply a bilateral affection, as it may be blown forwards from the naso-pharynx into the healthy side. On the other hand, at least one case has been reported in which unilateral nasal discharge occurred, although both frontal sinuses were affected. The flow of pus is often more or less intermittent, being worse when the patient stoops: again, it may accumulate in the throat in the

[1] *München. Med. Wochenschr.*, 1892, Nos. 4–6.

morning. This intermittency, influenced by posture, is suggestive of the antral origin of the discharge: a more constant flow may be in favour of its frontal source. Further, in some antral cases the discharge passes mainly, if not entirely, backwards into the naso-pharynx and pharynx, this symptom constituting the patient's chief complaint. This may depend upon the existence of a large accessory antral opening, which serves to drain the cavity in a backward direction. Pus from the posterior ethmoidal and sphenoidal cells tends to pass in the same direction, while from the frontal sinus the flow is mainly forwards.

(*b*) *Nasal Obstruction* may or may not accompany sinus suppuration, being dependent mainly on the presence of polypi; it may be unilateral or bilateral, partial or complete. The patient sometimes complains of its intermittent character, due in all probability to the varying amount of turgescence of the inferior turbinated bodies.

(*c*) *Pain* is a very variable symptom, and, as already indicated, may be absent throughout the whole course of the disease. It may be of the nature of headache, facial neuralgia, or toothache, sometimes slight, at other times occurring in severe paroxysms, often periodic in character. Some patients complain of a weight or fulness in the forehead, aggravated on stooping; others have associated with this an inability to concentrate their thoughts for any length of time, while mental work merely induces headache; mental depression sometimes accompanies ethmoid disease. Such symptoms may be entirely due to nasal obstruction, as they may disappear after the removal of the polypi, a fact which is also observed when free respiration through the nose is established in cases in which there is no sinus affection. I have seen these mental symptoms prove a source of great annoyance to two patients, suffering from suppuration in the frontal sinus, from whom a

considerable amount of brain-work was required. Too much importance should not be attached to the seat of the pain in cases of chronic suppuration. When this symptom is complained of in chronic antral suppuration, it is most commonly located in the supra-orbital region; frontal headaches are just as frequent in ethmoidal as in frontal sinus disease, while in the latter condition occipital pain has been in several instances noted. In sphenoidal sinus disease, pain on the vertex may be complained of, but occipital headache or painful sensations referred to the back of the eyes are also met with. The frequent combination of sinus affections merely increases the difficulty of estimating the value of pain as a diagnostic symptom. Pain or tenderness is rarely elicited by pressure upon the facial wall of the antrum. Tenderness induced by pressure on the floor of the frontal sinus in disease of that cavity, or upon the lachrymal bone in ethmoid affections, are signs of clinical value, which will be again referred to under special diagnosis.

(*d*) *Certain Secondary Symptoms* may arise in connection with sinus suppuration,—*e.g.* cough, dryness of the throat, and huskiness of voice, due to irritation of the upper air-passages from the purulent discharge,—while true asthmatic symptoms are occasionally met with. Indigestion is not infrequent, as a result of swallowing the offensive secretion.

(*e*) *Eye Symptoms.*—The intimate anatomical association of the various sinuses with the orbit and its contents, and the proximity of the sphenoidal sinus to the floor of the middle cranial fossa in the neighbourhood of the important oculomotor and optic nerves, sufficiently explain the occasional occurrence of eye symptoms in sinus disease. Generally speaking, we may group these symptoms and signs into two classes: those which are dependent upon displacement of the eyeball by mechanical pressure, such as occurs in ethmoidal, frontal, and

maxillary suppuration; and, secondly, those which result from compression or destruction of the optic or oculo-motor nerves, more commonly met with in sphenoidal sinus disease.

Although an upward and outward displacement of the eyeball may be met with in maxillary sinus suppuration, orbital complications probably arise less frequently in connection with this cavity than with the others. In disease of the frontal sinus, expansion of the bony floor, with or without the formation of an orbital abscess, causes swelling at the upper and inner angle of the orbit, and a downward and outward displacement of the globe. A similar displacement is more frequently associated with suppuration in the ethmoid cells in the absence of free drainage from these cells into the nose. The degree of forward projection of the eye (proptosis, exophthalmos) in these affections is mainly dependent upon the relation of the pressure to the equator of the eyeball.

Consequent upon displacement of the eyeball, limitations in its movements and disturbances in function follow. Diplopia, or double vision, and a narrowing of the field, especially for colours, are symptoms met with, while sometimes in severe cases there is an actual impairment of sight, an amblyopia or amaurosis. In association with these phenomena, pain, photophobia, interference with the flow of tears, swelling of the lids, and injection of the conjunctiva, make up a clinical picture which should always suggest the possibility of the existence of accessory sinus suppuration. With the actual formation of pus in the orbital cavity, these phenomena become aggravated. Primary orbital abscess is not common, and its occurrence should lead to an examination of the nasal sinuses.

As already indicated, the ocular complications of sphenoidal disease are mainly those resulting from implication of the optic nerve at the base of the skull. Optic neuritis followed by atrophy, with partial or complete loss of vision, may com-

plicate this condition. If the inflammation should extend and involve the oculo-motor nerves in the sphenoidal fissure, ptosis may be produced from implication of the third cranial nerve, while some variety of strabismus, or a general paralysis of the ocular muscles, may be induced by pressure upon the third, fourth, and sixth nerves. Intense neuralgia may be evidence of a neuritis of the ophthalmic division of the fifth nerve.

It is thus evident that the symptoms complained of by the patient may be varied in cases of chronic suppuration. It is inadvisable, therefore, for the surgeon to hasten to any conclusion without first making a careful examination of the nose. This is all the more necessary when we remember that many of the nasal phenomena above described may be induced by lesions confined to the nasal chambers themselves, and result from such causes as the exanthemata, syphilis, tubercle, atrophic rhinitis, malignant disease, foreign bodies, or naso-pharyngeal catarrh.

(2) EXAMINATION OF THE NOSE

A. Diagnosis of Chronic Suppuration in the Anterior Group of Sinuses

On account of the close anatomical relations of the different sinuses and their ostia, the diagnosis of chronic suppuration is often difficult, and is frequently arrived at only by a process of exclusion. We shall therefore endeavour to describe, step by step, the procedure which may be adopted in carrying out a systematic examination of these cavities. Even after a careful inspection of the nose, the surgeon may still be in doubt as to the real nature of the case, consequently he should have no hesitation in asking for a subsequent opportunity for further observation. As the intranasal appearances vary at

different periods of the day, it is advisable that the patient should not be seen on each occasion at the same hour.

Anterior and Posterior Rhinoscopy.—(a) Condition of the Nasal Mucous Membrane.—In many cases the nasal mucous membrane presents a red and swollen appearance; if the affection is unilateral, there is a marked contrast in this respect between the two chambers. The inferior turbinated body is frequently turgescent, preventing inspection of the deeper parts and necessitating the application to it of cocaine; occasionally the mucosa presents a dry, glazed appearance, associated with some atrophy of the inferior turbinated body. The nostril may be completely blocked by one or more large polypi, so that their removal is in the first instance necessary. One or more small polypi confined to the middle meatus are somewhat significant of sinus disease.

(*b*) *The Presence of Pus.*—Pus may be visible upon the inferior turbinated body, on the floor of the nose, or on the septum anteriorly, but the observer's attention must be turned particularly to two situations, namely, the middle meatus and the olfactory cleft. We shall in the first instance consider *a case in which pus is observed in the middle meatus.* The detection of a drop of pus in this region, under cover of the middle turbinated body, is highly suggestive of sinus disease, and the sinuses of the anterior group, the maxillary antrum, frontal sinus, and anterior ethmoidal cells, should be suspected. The position of the pus in the meatus affords no reliable guide as to which of these cavities is actually its source. If no pus be visible in this situation, it must not be at once assumed that there is no further necessity for considering these sinuses. We should at once proceed to investigate the case by other means at our disposal.

Posterior rhinoscopy may reveal a purulent discharge in the naso-pharynx; it may be detected in the choana of the sus-

pected side, or a favourable examination will disclose a drop of pus on the upper surface of the inferior turbinated body, that is, in the middle meatus posteriorly. This sign is of considerable value should we fail to detect any secretion in this meatus by anterior rhinoscopy.

Any one of the cavities above mentioned may be affected alone, or any two, or all three in combination: hence at the very outset a difficulty in diagnosis is met with. As the maxillary sinus is most frequently the source of the trouble, and as its anatomical position brings it most readily under examination, we proceed, in the first place, to investigate it.

I. Diagnosis of Chronic Suppuration in the Maxillary Sinus

(*a*) *Fränkel's Posture Test.*—It is now necessary to thoroughly remove every trace of pus from the anterior part of the middle meatus. This may be conveniently effected by means of a pledget of cotton-wool wrapped round the end of a probe. The patient is then directed to bend his head forwards in such a way that the vertex becomes dependent, while the cheek of the suspected side is at the same time turned uppermost. This posture is maintained for two or three minutes: the test sometimes loses its value if the head is not kept sufficiently long in this position. After the head has been raised, the middle meatus is again inspected. The reappearance of pus in this situation at once strongly suggests its antral source, and Fränkel's test is spoken of as positive. The position of the ostium maxillare under the roof of the antrum sufficiently explains this phenomenon. Although significant, it is, however, not conclusive. Even in antral suppuration Fränkel's test may prove negative, as I have seen in a number of instances, though at a subsequent examination

the reappearance of pus may be noted, a circumstance which may possibly depend upon the quantity of secretion that happens to be in the cavity at the time of inspection. Again, the position of the ostia of the ethmoid bulla and of the middle turbinated cell, towards the upper part of their respective cavities, will tend to make this test positive in anterior ethmoidal cell suppuration.

Greville Macdonald[1] asserts that, after the head has been dependent, he has found pus reappear in the middle meatus quite as frequently in frontal sinus suppuration. In spite of these possibilities, there is no doubt that the posture test, when positive, is of considerable value in the diagnosis of maxillary suppuration.

The following case presented certain features which were at first somewhat misleading:—

The patient, a young man, who was sent to me by Dr. T. Shennan, complained of considerable discharge of fœtid pus from the left nostril. Examination of the nose revealed the presence of a quantity of thick, creamy pus anteriorly and very high up in the middle meatus. As soon as this had been mopped out, a fresh quantity at once appeared; after applying the cotton-wool mop a second time, there was a further flow, thus making it difficult to clean that channel. After this had been accomplished, the head was placed in a dependent position; on again examining the nose, no pus was seen in the middle meatus. After an interval of five minutes, however, during which time the head was held erect, pus reappeared. The meatus was again cleaned, and the posture test repeated, with an immediate negative result. Three minutes later, however, pus was again visible. The position of the discharge anteriorly, the delay in its reappearance after the head had been held forwards, and a suspicion of tenderness on pressure upon the floor of the frontal sinus, suggested the source of the discharge from that cavity. On illumination, the left antrum was found to be opaque, and there was no subjective light sensation in the left eye: both frontal sinuses illuminated. The fœtid, bad-tasting discharge and the opacity of the antrum favoured an affection of the latter cavity. As it was possible, from the above phenomena, that both the left frontal and maxillary

[1] Allbutt's "System of Medicine," 1897, vol. iv.

sinuses might be affected, an exploratory puncture of the antrum was made, and a quantity of bad-smelling pus evacuated. The head was kept in the erect position for ten minutes after this procedure, and pus no longer appeared in the middle meatus. The patient rapidly recovered after irrigation of the antrum. There was no disease of the anterior ethmoidal cells.

The next case not only illustrates the negative character of the posture test, but is an example of one in which the discharge from the antrum passed mainly, if not entirely, into the naso-pharynx, in all probability from a large accessory maxillary ostium :—

For six months the patient had complained of a fœtid, bad-tasting discharge, which was constantly accumulating in his throat. He rarely required to use his handkerchief, and if at any time there was purulent discharge upon it, he was not conscious of its coming from one nostril more than the other. Indeed, he affirmed that his symptoms were almost always referable to the back of his nose and throat.

On anterior rhinoscopy, there was no pus visible in either nasal cavity, and the middle meatus on each side was free from discharge. On the right side, pus could be seen through the anterior naris, lying upon the posterior wall of the naso-pharynx. On posterior rhinoscopy, pus was visible on the right side of the free edge of the septum, and upon the upper surface of the right inferior turbinated body. Fränkel's test was negative, no pus appearing in the anterior part of the middle meatus. There was noticed, however, after the test, on the inner or mesial surface of the inferior turbinated, far back in the nose, a small quantity of pus, in a position which certainly suggested that it might have flowed from an accessory antral opening. Shortly after the posture test had been carried out, the patient complained of an increase of discharge in his throat. On illumination, the right antrum was opaque, and there was no subjective light sensation in the right eye. The diagnosis of suppuration in the right maxillary sinus was confirmed when the cavity was opened through the socket of a diseased first molar tooth.

(*b*) *The Suction Test.*—Seifert[1] and Réthi[2] have recently advocated the use of the following method in diagnosis:—After

[1] *Rev. hebd. de laryngol.*, December 16, 1899.
[2] *Wien. klin. Rundschau*, October 22, 1899.

all trace of pus has been removed from the nasal chamber, the nozzle of a Politzer's bag, already compressed, is introduced into the nostril of the suspected side; the anterior nares are closed, and, when the patient is directed to swallow, the bag is allowed to suddenly expand. The object of this manœuvre is to withdraw by suction some of the secretion from the sinuses. The nose is again inspected, and pus sought for in the middle meatus. Should it be visible in that situation, its sinus origin is suggested, but there still remains the difficulty of definitely tracing it to one or other of the ostia situated in that channel.

(*c*) *The Illumination Test.*—The method of transilluminating the antrum, and the results obtained by it, have been fully described in Chapter VII., pp. 108–119. The reader is referred to what has been said there upon the value of this test.

Regnier and Glover[1] have suggested the use of the X-rays for testing the transparency of the sinuses. These observers recommend this method of illumination in preference to the ordinary electric lamp usually employed. The rays are applied through cylindrical focus tubes, the tube being fixed upon a light stand, which can be brought within proper distance of the patient's head without inconveniencing him. The surgeon wears caoutchouc gloves to protect his hands. In examination of the face, all the accessory cavities become visible at the same time. According to the observations of Wertheim,[2] pus in the accessory sinuses does not prevent the transmission of the X-rays. It is otherwise, however, in the case of a solid tumour, so that we are thus provided with the means of making a differential diagnosis between abscess and tumour of the antrum. Until this method of research is brought within more reasonable reach of the clinician, it is not likely to supersede the transillumination in common use.

[1] *Lancet*, London, February 24, 1900. [2] *Loc. cit.*

If the various features of the case already enumerated, when studied together, still fail to convince the observer that the antrum is affected, he must proceed, through an exploratory puncture, to inflate or syringe out the cavity. The presence of pus in the middle meatus, associated with some degree of fœtor and bad taste, and the existence of one or more carious teeth, are suggestive of antral suppuration. If, further, discharge reappears after stooping, and the cheek of the suspected side is opaque on illumination, the evidence is strongly presumptive. It is, however, only conclusive when pus is blown or washed out of the cavity.

Before proceeding to carry this out, the nasal chamber, including the middle meatus, must be carefully cleansed of every trace of pus by means of cotton-wool mops, or by syringing. This cannot be too strongly insisted upon, otherwise the test loses its value. If the lotion injected through the maxillary sinus passes thence through a nasal cavity which has not been thoroughly cleaned, there is no guarantee that the discharge washed out was not secreted in the frontal sinus or anterior ethmoidal cells. This fallacy is avoided by preliminary cleansing of the nose. One of the following methods of puncture may be employed :—

(*d*) *Exploration through the Outer Wall of the Inferior Meatus of the Nose.*—This is, as a rule, a simple procedure, introduced by Moritz Schmidt,[1] and is the most serviceable in doubtful cases, because in the event of the cavity proving to be healthy, no inconvenience results, such as might follow a temporary opening through a septic cavity like the mouth. The area selected lies immediately below the attachment of the anterior end of the inferior turbinated body, where the bone is thinnest. That structure and the mucous membrane of the outer wall of the inferior meatus are cocainised: if

[1] *Berl. klin. Wochenschr.*, 1888, No. 50.

the turbinated body be turgescent, and tend to obscure the wall beneath it, the cocaine will reduce the swelling. A fine Lichtwitz's trocar and cannula, a Krause's or a Sprenger's trocar, is then introduced through a Thudichum's nasal speculum, the instrument being guided by the eye, with the aid of good illumination. The trocar should be directed outwards and upwards; a firm push may be necessary before the wall is perforated and the cavity entered. The sensation of passing through bone, the somewhat sudden release of the point of the instrument and its mobility, will testify to its presence in the sinus. Occasionally a case is met with in which the bone offers so much resistance that some other route must be adopted.

The following case illustrates an exceptional form of accident which occurred once in my hands when making an exploratory puncture:—

The patient, Miss B., was sent to see me at the Dispensary by Dr. Haig Ferguson. Her symptoms suggested some affection of an accessory sinus, and she maintained that the trouble existed in both sides of her nose. After an objective examination had been made, the diagnosis remained somewhat doubtful, as there was very little secretion, and this was mainly of a muco-purulent character, while both antra illuminated very faintly; there was a small polypus growing in each middle meatus. It was decided to puncture the left antrum through the outer wall of the inferior meatus. This was carried out in the ordinary way with apparent success, the trocar being felt to pass through a bony wall; its point was then felt to move with some freedom. A small quantity of warm boracic lotion was injected from a Higginson's syringe through the cannula, the syringe working with some difficulty. The patient at once complained of pain, but it was not until a second attempt was made to squeeze the ball of the syringe that a swelling was noticed upon the left cheek. On palpating this, an emphysematous crackling sound was obtained. It was therefore evident that the instrument had passed in front of the anterior wall of the sinus into the soft tissue of the cheek. In all probability the cavity resembled, to some extent at least, that figured on Plate VIII. The swelling disappeared in a few days without any untoward result. At a later date both antra were opened through the canine fossæ, and a radical operation performed.

It is rare to find pus flow outwards through the cannula, so that the condition of the cavity must be investigated by the inflation of air or by washing it out. For the purpose of inflation, a piece of indiarubber tubing, to which a Politzer's bag is attached, is passed over the outer end of the cannula. The operator's left hand holds the nasal speculum and instrument, while with the right the bag is compressed. The middle meatus is carefully inspected during the act, and the secretion looked for in it. In order to wash out the sinus, a Higginson's syringe with a fine nozzle is attached to the cannula, and a warm boracic or warm sterilised salt solution is gently injected. During this procedure the patient should lean slightly forwards over an empty basin, and as the stream of fluid, passing through the natural orifice of the antrum into the nasal cavity, falls into the basin, it is examined for the detection of abnormal secretion.

(*e*) *Exploration through the Natural Opening or Ostium Maxillare.*—The introduction of a suitably curved cannula through the hiatus semilunaris into the orifice of the antrum, while recommended by some operators for diagnostic purposes, is by no means an easy procedure. The concealed position of the orifice renders it difficult; and when the mucous membrane is swollen, and small polypi surround the hiatus, the operation is rendered still more difficult. A Hartmann's curved cannula is employed for this purpose.

(*f*) *Exploration through the Socket of a Carious Tooth.*—This procedure is a therapeutic as well as a diagnostic one. When there still exists some doubt as to the exact condition of the maxillary sinus, a diseased tooth may be first extracted, its socket drilled, and the cavity then washed out. Should pus be present, a suitable plug can then be adapted, as will be described under Treatment.

(*g*) *Exploration through the Canine Fossa.*—For diagnostic

purposes only, this route is rarely employed. Should the examiner feel tolerably certain that he is dealing with antral suppuration, and in the event of the patient possessing a complete and sound set of teeth, a somewhat rare distinction, an opening may be made in this situation. This will serve to confirm the diagnosis, and at the same time provide a channel for the treatment of the diseased sinus.

By adopting the above routine practice, the surgeon will probably have convinced himself of the existence of chronic antral suppuration, or, on the other hand, have satisfied himself that the cavity is healthy. If he has failed to do so at the first sitting, a second or a third examination may prove more satisfactory. By establishing this diagnosis, he has, however, probably not excluded the possibility of a coexisting frontal sinus or anterior ethmoidal cell suppuration. Although the antrum in a great number of cases is alone diseased, we know how frequently two or more of these cavities are affected in combination. When a considerable quantity of pus is observed in the nose, and only a scanty amount is washed out of the maxillary sinus, the suspicion of some further sinus mischief should be aroused. In some cases a diagnosis of frontal or ethmoidal suppuration is only made after the antrum has been for some time under treatment. If the examination has demonstrated the fact that the antrum is healthy, or if pus still flows into the middle meatus after that cavity has been washed out, it is necessary to proceed to a further investigation of the nose.

II. Diagnosis of Chronic Suppuration in the Frontal Sinus

Under General Symptomatology, certain points were referred to which suggested that the source of the pus might be in the

frontal sinus. Amongst these were noted its greenish colour and the absence of fœtor; further, the more continuous flow of the discharge, its situation high up and anteriorly in the nose, and its non-appearance after the head had been bent forwards, were also commented upon. The frequent combination of sinus affections, the close anatomical association of the various ostia, and the frequent changes in the position of the patient's head, must necessarily make these signs of little diagnostic value, even should all of them coexist.

(*a*) *Reappearance of Pus in the Middle Meatus after Syringing the Antrum.*—After the antrum has been syringed and the middle meatus carefully cleansed of every trace of pus, the patient should be directed to sit quietly for ten or fifteen minutes without inclining his head forwards even to a slight degree. At the end of this interval the nose is again examined, and if a drop of pus be observed in the middle meatus, a suspicion of its origin in the frontal sinus is raised. The position of the ostium maxillare makes it impossible for secretion to pass from the antrum into the nose in so short a space of time. This observation is assisted by the previous insertion of a wool tampon against the lower and posterior part of the hiatus semilunaris, as recommended by Grünwald, so that the possible escape of secretion from the antrum is thus hindered. This test, however, does not exclude the possibility of some ethmoidal cell suppuration which is so frequently present along with frontal sinus disease.

(*b*) *Tenderness on Pressure upon the Floor of the Frontal Sinus.*—In applying this test, pressure must be made with the finger upon the thin bony floor of the sinus beneath the inner third of the supra-orbital margin. Care must be taken to avoid the supra-orbital nerve lying somewhat externally, and, further, pressure must not be made on the bony margin of the orbit. It is a good plan to apply the test simultaneously upon

both sides, the patient being asked to press down upon the fingers. A more equal distribution of pressure and a more accurate observation are thus obtained. It is very necessary to differentiate between a surface soreness, such as is elicited even in healthy individuals, and the more deep-seated true pain. In many cases the patient readily admits the existence of this tenderness, and considerable reliance may be placed upon this sign as an aid in diagnosis, when taken in conjunction with other phenomena; on the other hand, the patient's statement cannot always be relied upon. Percussion of, or firm pressure upon, the thicker anterior sinus wall may fail altogether to elicit tenderness over an affected cavity. In one of my cases the patient was positive about the existence of pain on pressure beneath both sinuses. The sinus on one side was opened, and found to be healthy. On the other side the cavity was found to be diseased.

(*c*) *Redness, Œdema, or Swelling in the region of the Sinus.*—Although these signs are more frequently evidence of an acute exacerbation, possibly resulting from an unusual retention of discharge, they may occur as transient phenomena in chronic cases. Careful observation and palpation may detect some slight degree of œdema or thickening upon the lower part of the forehead or in the upper eyelid. The patient may volunteer the statement that he has observed temporary swelling in this region. It has been stated that, after percussion over both sinuses, the redness of the skin thus produced remains for a longer period over an affected cavity than upon the healthy side, a point upon which I have never been able to satisfy myself.

(*d*) *Illumination of the Frontal Sinus.*—A full description of this procedure will be found upon p. 120. I have not found this test of any diagnostic value in chronic suppuration of the frontal sinus.

So far, therefore, in the diagnosis of frontal sinus suppuration we have to rely upon the exclusion of antral disease, and upon the reappearance of pus in the middle meatus of the nose shortly after syringing out the latter cavity when it is affected. As this latter sign is consistent with suppuration in the anterior ethmoidal cells, we must endeavour to elicit tenderness on pressure upon the floor of the frontal sinus, and investigate the occurrence of œdema or redness of the skin of the forehead and upper eyelid. While all these signs furnish suggestive and even presumptive evidence of the disease, it is necessary to catheterise the sinus before establishing a diagnosis with any degree of certainty.

(*e*) *Probing and Catheterisation through the Ostium Frontale.*—The method of probing the frontal sinus has been fully considered in Chapter V., and the reader is referred to p. 47 for an account of the procedure. The probe test should be supplemented by the introduction of a frontal cannula. For this purpose Hartmann's may be used. I have found the pattern introduced by Brown Kelly of Glasgow very satisfactory, and fulfilling all the necessary requirements. To the proximal end of the catheter a piece of rubber tubing and a Politzer's bag are attached—inflation being then carried out during careful inspection of the interior of the nose. Pus mixed with air may then be seen to be driven downward. Gentle syringing of the cavity may be substituted, and pus looked for in the lotion.

The frequency of an associated frontal and ethmoidal suppuration undoubtedly increases the difficulty of diagnosing the existence of the former. If a considerable quantity of pus be expelled by inflation or syringing, suspicion of an affection of the larger cavity will be raised; but it may be necessary to treat the ethmoid condition before it is possible to

recognise that pus is coming from a higher source. There still remain some cases in which, in the present state of our knowledge, an external opening into the frontal sinus is necessary before an exact diagnosis can be arrived at. We must duly weigh all the clinical phenomena taken together, and not seek to draw a conclusion for or against frontal sinus suppuration from this or that individual sign.

The following case may be quoted as illustrating the method of arriving at a diagnosis of the existing condition in a somewhat complicated case :—

The patient, who was seen in consultation with Dr. Burn Murdoch, had suffered for many years from nasal polypi, which completely filled both cavities. These had been removed on several occasions, but always recurred after a varying interval of time. Along with the polypi there was always present a certain amount of purulent discharge. The patient suffered very considerably from headaches.

On examination, I found both nostrils completely blocked with polypi. After several sittings these were all snared, both middle turbinateds were then removed, and the bony walls of some of the anterior ethmoidal cells were broken down with forceps. Both antra illuminated ; but in order to make the diagnosis certain, the left antrum was punctured and washed out, with a negative result. The right was therefore also assumed to be healthy. Both frontal sinuses also illuminated ; there was considerable tenderness on pressure upon the floor of each of these cavities. In order to ascertain whether any of the purulent discharge had its source above the ethmoidal cells, each frontal sinus was probed. As the entrance to these cavities appeared easy of access, especially upon the left side, each nasal chamber was carefully cleansed of every trace of pus, and the frontal cannula was passed up into each sinus in turn. The distance travelled by the instrument and the mobility of its point testified to its position within the frontal cavity. On inflation, pus mixed with air was readily seen to be blown down into the upper part of the nasal chamber. This test was repeated upon more than one occasion. As the intranasal treatment benefited the patient considerably, she declined further interference, notwithstanding a continuance of the discharge and occasional headaches.

III. Diagnosis of Chronic Suppuration in the Anterior Ethmoidal Cells

We have already drawn attention to the fact that suppuration in the frontal sinus is very frequently associated with the same affection in the anterior ethmoidal cells. Similarly, the latter cells may also be affected in association with maxillary sinus disease, though by no means with the same frequency. It may not be possible, therefore, to accurately establish the diagnosis of ethmoid cell suppuration without first satisfying ourselves as to the condition of these other cavities. Hence a diagnosis may be arrived at by a process of exclusion.

The examination of the ethmoid region will be greatly facilitated by the removal of the greater portion of the middle turbinated bone, if this has not been already done when exploring the frontal sinus. If this bone should contain an air-cell, the latter may be found to contain pus, while its lining membrane may be swollen and thickened. The field of observation is thus considerably enlarged, and a number of small polypi, with pus oozing from between them, may possibly be detected. If a fine probe, with its extremity bent somewhat outwards, be pushed upwards between the polypi in the direction of the ethmoid cells, an increased flow of purulent secretion would then probably be observed. Some writers have asserted that a probe thus introduced would come in contact with granulation tissue and areas of carious bone. It must be borne in mind, however, that it is very difficult in this situation to conclude from the sense of touch whether the bone is actually carious, and whether the probe is in a cavity lined with granulations or with a healthy mucous membrane. After completing this part of the examination, the polypi should be removed, and on a subsequent occasion the nose should again be carefully inspected, and the source of the pus

sought for. If the formation of the nasal chamber permits the examiner to localise the position of the hiatus semilunaris and bulla ethmoidalis, he should proceed to occlude the former by means of a cotton-wool tampon. The nose should then be cleaned, and an attempt made with a probe or cannula to enter the cells lying above the bulla, by passing the instrument upwards and outwards. Inflation through the catheter may blow pus from the cells into the middle meatus. If the ethmoidal cells situated more anteriorly and opening into the upper end of the infundibulum are catheterised, doubt will naturally arise in some cases as to whether pus blown down from this region has actually been secreted in these cells, or has trickled down from the frontal sinus at a higher level. By repeated observation, by the removal of small polypi and portions of the bony framework of the lateral mass of the ethmoid, the source of the pus is thus gradually followed up and ascertained. This procedure not only leads to a diagnosis of the true condition, but forms in a large measure the preliminary stages of treatment.

B. Diagnosis of Chronic Suppuration in the Posterior Group of Sinuses

THE SPHENOIDAL SINUS AND POSTERIOR ETHMOIDAL CELLS

We have thus far endeavoured to trace the source of the suppuration in those cases in which anterior rhinoscopy has revealed the presence of pus in the middle meatus, and in which, on posterior rhinoscopy, pus has been detected upon the upper surface of the posterior extremity of the inferior turbinated body. A diagnosis of maxillary, frontal or anterior ethmoidal cell suppuration has probably been established. Let us now assume that we have to deal with a patient in whom, on anterior rhinoscopy, the middle meatus is found free from

pus, but *purulent discharge is seen to lie in the olfactory cleft* between the middle turbinated body and the septum nasi. Suspicion is then directed to the posterior group of sinuses, viz. the posterior ethmoidal cells and the sphenoidal sinus. The similarity of the nasal phenomena which may be presented by each, and the fact that their close proximity renders them liable to be affected at the same time, makes a differential diagnosis sometimes difficult. We are therefore led to consider these air-spaces together. The clinical differentiation into two groups is not always so simple as the anatomical basis would indicate, as pus from the posterior ethmoidal cells may find its way into the middle meatus. Again, owing to the position of the ostia of the posterior group, there is a greater tendency for the secretion to pass backwards into the naso-pharynx, and thus leave the interior of the nose more or less free. It must not be assumed, therefore, that in the absence of pus in the olfactory cleft, there is no affection of the posterior group of sinuses. If the disease should coexist in one or more sinuses of both groups, the diagnosis is still further complicated. It may only be after excluding or treating disease in the anterior sinuses that we are led to suspect its existence in the posterior ethmoidal or sphenoidal cavities. Our knowledge of chronic suppuration in the latter cavity is largely due to the observations of Schäffer, Grünwald, and Hajek.

(*a*) *Anterior Rhinoscopy.*—When *pus* is observed in the olfactory cleft, it should be carefully mopped out with cotton-wool pledgets, and the region again inspected. If more secretion becomes visible, suspicion is aroused of its probable source in the posterior ethmoidal cells or sphenoidal sinus. The removal of a crust in the same locality, followed by a discharge of pus, is also significant. Sometimes the olfactory fissure is occluded by swelling of the mucous membrane, and no pus is visible. If, under these circumstances, a purulent discharge

follows the forcible introduction and withdrawal of a probe protected with a cotton-wool tampon, the same inference may be drawn.

Polypi may also be met with in this situation and upon the middle turbinated body.

(*b*) *Posterior Rhinoscopy* plays a somewhat more important part in the examination of these cases. Owing to the situation of the posterior ostia, pus tends to pass backwards into the naso-pharynx, rather than forwards into the nose. Inspection of the vault probably reveals the presence of one or more crusts adherent to the mucous membrane. Intermixed with the crusts some fluid secretion may also be visible. In these cases a careful examination of the choanæ must be made, because the presence of pus within one or other of these apertures is always very suggestive of the origin of the secretion in an accessory cavity. Should the discharge at the same time be visible upon the upper surface of the middle turbinated body, *i.e.* in the superior meatus, it is still more suggestive. When it occurs in this latter situation, the source of the pus from one of the sinuses of the anterior group is excluded on anatomical grounds. If it is difficult to obtain a thorough inspection of the naso-pharynx, cocaine should be applied, and the palate hook placed in position. The clinical picture presented by some of these cases is not unlike what is met with in that form of naso-pharyngeal catarrh which is associated with crust formation. Many cases are unsuccessfully treated as such for a considerable length of time; hence it is very important, for diagnostic reasons, to detect the presence of pus upon the middle turbinated body by posterior rhinoscopy. It should be made a routine practice in all cases of naso-pharyngeal catarrh to inspect and probe the interior of the nose, keeping in mind the possibility of a sinus affection.

(*c*) *Ophthalmoscopic Examination* will prove of value in

some instances; the eye symptoms that may be met with have already been referred to (p. 152).

While the conditions noted above are suggestive of suppuration in the posterior group of sinuses, it is as necessary here as in the case of the anterior group to accurately locate the source of origin of pus. To effect this, the middle turbinated bone should be removed. It is probable that in some cases this has already been partly done, where disease of the anterior ethmoidal or frontal sinuses has either been suspected or has actually been found to exist. It is true that cases are occasionally met with where a wide olfactory cleft permits of inspection of the sphenoidal orifice by anterior rhinoscopy, but such cases are extremely rare. Moreover, in some instances the superior turbinated body interferes with direct inspection of that opening, which is subject to variation in its position. The middle turbinated bone should therefore be removed (p. 191).

(*d*) *Inspection, Probing, and Catheterisation of the Ostium Sphenoidale.*—After an interval of two or three days, the nose should be again inspected by anterior rhinoscopy, and all traces of crusts and purulent discharge in the post-nasal region thoroughly removed. This procedure demands the same care as it did in the case of the maxillary and frontal sinuses. The sphenoidal opening may then become visible. Should pus be seen issuing from it, the diagnosis is established. Should no discharge be visible, a cotton-wool tampon must be packed against the ostium, and left in position for half an hour. On its removal, the presence of pus on the deep surface of the wool will testify to its origin in the sphenoidal cavity. The method of catheterising the sphenoidal sinus has been described in Chapter V. After catheterisation, it is recommended that a probe should next be introduced, and an attempt made to ascertain the condition of the walls of the cavity. Great care should attend this manipulation, especially when the roof of

the cavity is under examination. As the sinus varies considerably in size in different skulls, it is impossible to form an accurate estimate of the distance to which the probe may be passed.

If on anatomical grounds it is impossible to see the sphenoidal orifice by direct inspection, some authors advocate and practise perforation of the anterior wall of the sinus with a sharp instrument. Thus Schäffer has employed a spoon probe, while Spiess[1] recommends an electro-motor trephine.

Attention should next be turned to the diagnosis of suppuration in the posterior ethmoidal cells, whether occurring alone or in conjunction with suppuration in the sphenoidal cavity. The sphenoidal orifice should be plugged with a cotton-wool tampon, after careful cleansing of its vicinity. If pus then collects in the nose anteriorly to the plug, or even stains the nasal surface of the wool, a suspicion of ethmoidal disease is raised. A probe, with its point bent outwards, should then be passed in the direction of these cells, and an attempt made to further investigate their condition.

[1] *Arch. f. Laryngol.*, Berlin, Bd. vii. Heft 1.

CHAPTER X

THE TREATMENT OF SUPPURATION IN THE ACCESSORY SINUSES

A. Treatment of Acute Suppuration

ACUTE suppuration in the accessory nasal sinuses may heal spontaneously, or may pass into a chronic condition. Some cases require early surgical interference, owing to the acute and threatening character of the symptoms. The duration of this stage varies considerably, and is dependent not only upon the severity of the infection, but on certain anatomical conditions which favour imperfect drainage. Amongst these may be enumerated the position of the ostium as in the antrum, the small size of the openings, and incomplete subdivisions of the cavity due to partitions. I have seen acute suppuration of the frontal sinus heal without any surgical operation after the discharge had persisted for seven weeks, while an acute suppuration of the antrum, seen a week after its onset and treated by palliative measures, lapsed into a chronic condition. In the treatment of the acute stage various simple remedies are employed, mainly with the object of reducing the nasal turgescence, and thus favouring freer drainage. The patient should be confined to bed; and, in the case of the maxillary and frontal sinuses, hot compresses or ice applied to the cheek and forehead relieve the pain to some extent. Frequent inhalations of menthol vapour, prepared by adding menthol crystals to hot

water, or administered in a 10 per cent. alcoholic solution from an inhaler, greatly relieve the symptoms. A weak cocaine spray 2 to 3 per cent. effects a similar purpose. The internal administration of salol is also strongly recommended by some.

The severer cases, however, require careful watching, and if the symptoms are very acute, it may be necessary to open the sinus, or enter it through the natural orifice, and wash out the contents. Complete and permanent relief has resulted from a single irrigation in such cases. If the pain continues severe, or head symptoms supervene, operation should not be delayed. In the case of the maxillary sinus, an opening through the outer wall of the inferior meatus, made with a Krause's trocar and then enlarged, may suffice. The surgeon, however, will find that an opening in the canine fossa, or through a gap in the situation of a molar tooth, followed by packing of the cavity for a week or ten days, will give a successful result. The formation of an orbital abscess must be at once dealt with. Opinions differ as regards the time of opening the sinus in the less severe cases, where, after the disappearance of all subjective symptoms, the purulent discharge continues. Avellis [1] is in favour of operating after three weeks, while others recommend delay for six weeks. In the case of acute suppuration of the frontal sinus detailed in Chapter VIII., the discharge altogether ceased spontaneously after seven weeks. In all cases the surgeon must be guided both by the amount and character of the pus. If it recurs in gradually diminishing quantities and becomes less purulent, even though it continues over a period of several weeks, operation may still be safely delayed. The method of operating upon the different sinuses is more fully described under the treatment of chronic suppuration. In acute cases, however, curetting of the interior of the cavity is not necessary, and the condition tends to heal without prolonged after-treatment.

[1] *Arch. f. Laryngol.*, Berlin, Bd. iv. Heft 2.

B. Treatment of Chronic Suppuration

In considering the treatment of chronic suppuration, we must be guided by general surgical principles, and endeavour to determine in each case what pathological conditions are present, and how they may be most satisfactorily dealt with. In all cases in which nasal polypi and hypertrophies of the mucous membrane exist, they must be removed, so that partial occlusion of the natural orifices is got rid of, and freer drainage thus established. In the case of the antrum, diseased teeth should be extracted, whether they can be definitely proved as the causal factor or not. When there is a polypoid condition of the lining membrane of the sinus, or when there is caries of the osseous walls, steps must be taken to deal with these conditions. The frequency of associated sinus mischief must be borne in mind, and the possibility that the sinus under treatment may be reinfected by pus which is being secreted in one of the other cavities, must not be lost sight of. Until these points are elucidated and dealt with, all the conditions of successful treatment cannot be fulfilled.

I. TREATMENT OF CHRONIC SUPPURATION OF THE MAXILLARY ANTRUM

In the treatment of chronic suppuration of this sinus, one of two courses may be adopted: either to open the sinus through the socket of a tooth and regularly wash it out for a varying period of time, or to perform a radical operation. Some difference of opinion exists regarding the choice of the operation. There are undoubtedly a number of cases in which a course of irrigation suffices to effect a cure, though no definite statement can be made as to the length of time necessary to bring this about. There are other cases,

again, which from the first are doomed to failure by this method, but unfortunately we are not always able to say which these cases are. When the lining membrane of the antrum has been converted into polypoid tissue, only the radical operation will prove successful; when such changes have not taken place, a reasonable trial should be given to the simpler line of treatment. It is difficult, if not impossible, to say what the condition of the mucosa is, unless one first opens into the sinus to see, and the ordinary alveolar opening does not permit of inspection of the cavity. The duration of the affection does not altogether help us, as cavities which have discharged pus for some years are cured under simple lavage, while those of more recent origin may fail to do so. I have not found illumination of any material assistance on this point: the density of the opacity does not guide us as to the exact condition of the lining membrane. In uncomplicated antral cases, therefore, if there is no reason to believe that any of the other sinuses on the same side of the nose are affected, the irrigation treatment should be given a fair trial. If, however, associated ethmoidal or frontal sinus suppuration exists, more radical methods should be resorted to from the first. Irrigation treatment appeals to the patient, to whom, however, the possibility of failure should be explained. The operation can be readily performed under nitrous oxide anæsthesia. It does not confine the patient to the house, and the after-treatment can be carried out quite independently of the medical attendant. At the same time, in a certain proportion of cases this method proves a failure; and after a tiresome course of syringing, and perhaps at some considerable inconvenience to himself, the patient must submit to the radical operation. The question as to whether the presence or absence of nasal polypi will assist us in determining the condition of the lining membrane of the antrum, and aid us in our prognosis with regard to

treatment by lavage, is worthy of extended observation. Cases of chronic suppuration of that cavity, uncomplicated by disease in the ethmoid cells or frontal sinus, should alone be considered in this connection. Do the cases without nasal polypi heal more readily under irrigation than those in which polypi are present? My own observations upon this point are too limited to permit of any general conclusion being drawn, but they are in favour of the view that the cases associated with nasal polypi do not respond so readily to simple treatment as those without them.

A. Treatment by Lavage

In all cases in which nasal polypi and hypertrophies are present, they must, in the first instance, be removed, so that there may be no interference with the free escape of the lotion through the natural antral orifice. For purposes of irrigation two routes are open to us, the nasal and the buccal. It is hardly necessary to do more than merely refer to irrigation through the nose. The natural orifice of the antrum may be at once dismissed, as it is impracticable for the patient and usually so for the surgeon. An opening made through the outer wall of the inferior meatus of the nose, below the anterior end of the inferior turbinated bone, finds favour with some who have successfully practised it. It certainly has the advantage of not being connected with a septic cavity like the mouth; on the other hand, the patient often has a difficulty in finding the opening, which, further, has a tendency to rapidly close. It may be mentioned in passing, that a cure has, in one or two cases, been reported, following upon a single puncture of the nasal wall of the cavity.

The Alveolar Opening.—This certainly forms the most convenient route and the one most frequently selected. By adopting this method, two important requirements are at once

met, namely, the removal of a diseased tooth—the possible causative factor—and the opening of the cavity at its most dependent part. The disadvantage lies in establishing a communication with the mouth; this may be, however, largely counterbalanced by inserting a solid plug into the aperture, instead of the open drainage-tube formerly employed.

The operation can be performed under nitrous-oxide gas, bromide of ethyl, or chloroform anæsthesia. The first or second molar by preference, or the second bicuspid tooth if diseased, should be extracted, the socket pierced by one of the numerous forms of antral perforator, and the cavity entered. Should a suitable gap exist between sound teeth, it may be utilised for a similar purpose. It is well to emphasise the fact that too small a hole must not be made through the alveolus. All the teeth in the upper jaw should be thoroughly inspected, and where disease is detected, either careful stopping or removal should be insisted upon, as it is foolish to attempt treatment of the sinus while carious teeth may be in connection with it.

The cavity is next washed out with a warm sterilised or weak antiseptic solution, and a solid obturator is prepared for insertion. As our primary object is rather to maintain the opening thus made, so that syringing may be regularly carried out, and not to establish a dependent drain, it is better to employ a solid plug instead of an open drainage-tube. In the latter case the patient is annoyed with the dribbling of pus into the mouth, while there is always an open track for fresh infection from that source, and for the introduction of food particles. To obviate this latter risk, some operators who use the open drain recommend plugging of the tube during meals. If, however, the sinus be systematically syringed, any disadvantage which might accrue from a temporary accumulation of pus within it is certainly less than the annoyance and risk of a tube which is always open. An obturator made of vulcanite,

caoutchouc, or silver gilt, proves very serviceable; the proper length of the plug is ascertained by measuring with a probe the length of the track which has been made in the alveolus. Obviously it is very necessary to have this securely fastened in position, so that it may neither slip into the cavity nor drop into the mouth. Various methods are employed for this purpose. If the patient already wear a dental plate, the plug may be attached to it, the wound in the alveolus being temporarily plugged with gauze while this is being prepared. Its attachment may be made to a neighbouring tooth by some form of ring, or, in the absence of teeth, a plate should be moulded to the jaw. Many of these points are best attended to by the dentist. If all the teeth are present and perfectly sound,—a state of things not very frequently met with in these cases,—a healthy tooth should not be sacrificed. The sinus may then be opened through the canine fossa, care being taken, after perforating the bone, to securely fix the plug. If, however, this method has to be adopted, I am in favour of making a fairly large opening in the fossa, inspecting the cavity through it, curetting the lining membrane if necessary, and packing the sinus with gauze or worsted,—in other words, performing the radical operation.

The patient should be carefully instructed with regard to the method of syringing the cavity; some form of ball syringe, or the ordinary soft rubber Higginson syringe, to which a narrow nozzle has been adapted, will suit the purpose. Various non-irritating lotions are recommended: a warm salt solution (ʒi–Oj), a warm boracic or an alkaline lotion may be employed; a mild astringent, such as sulphate of zinc (2 grs.–℥i), is sometimes used at a later stage. Protargol has been highly recommended by Alexander[1] of Berlin; he introduces daily 50 c.c. of a 5 per cent. solution after syringing

[1] *Arch. f. Laryngol.*, Berlin, Bd. vii. Heft 1.

the cavity with sterilised water. A change of lotion is sometimes beneficial when healing is delayed.

The plug having been removed, the nozzle of the syringe is introduced into the alveolar opening, and the patient, inclining his head forwards so that the lotion may flow outwards through the anterior naris, gently syringes the cavity. It is important to bear in mind that forcible syringing must be avoided; I feel certain that with the head inclined forwards, infection of the anterior ethmoidal cells, or even of the frontal sinus, may, and does sometimes, occur as the result of too vigorous syringing. If the antrum be filled with water experimentally and the head tilted forwards, some of the fluid is observed to flow readily along the infundibulum and fronto-nasal passage into the frontal sinus. Blocking of the hiatus semilunaris from polypi, or a swollen condition of the mucosa, would still further facilitate this. At the commencement of treatment the cavity should be syringed out twice or even three times daily, if the discharge is profuse and fœtid. Later, as it gradually diminishes in quantity and the symptoms disappear, irrigation is carried out with less frequency, until a week elapses without syringing. If the lotion then passes through the cavity in a perfectly clear stream, and if at the end of a second and third week the same result is again noted, it may be considered safe to remove the plug and allow the track to close. Occasionally one finds that a minimum of discharge will cease altogether by discontinuing the irrigation, which has really tended to maintain a slight catarrh of the mucous membrane. The alveolar opening, as a rule, readily closes; the obturator should be shortened, so that the upper part of the track may first close before the plug is finally removed.

The time required to obtain so desirable a result varies considerably—from a few weeks to several months. The question naturally arises as to the length of the period which is necessary

to continue lavage in those cases which do not readily respond to treatment. It is impossible to estimate this from the point of view of time; more reliable information is to be obtained by carefully observing the amount and the character of the discharge, especially the latter. If after a fair and consistent trial extending over three or four months there still remains a definite quantity of thickish pus or muco-pus, unaffected by a change of lotion, the question of further treatment should be considered. If at the same time there is no intranasal disease, and no evidence of suppuration in any of the other cavities which may be adversely influencing the antrum, and the patient expresses himself as weary of the constant irrigation, the surgeon may reasonably decide upon more radical measures.

As an example of a case of long-standing discharge cured by lavage, and as affording some indication of the period of time during which irrigation was carried out, we may append the following notes:—

CASE A. was that of a gentleman who gave a very definite history of discharge from the right nostril during eight years. It had apparently originated after an attack of influenza, and varied somewhat at different times in its severity, the symptoms being more in abeyance during the summer. The discharge was slightly fœtid. There were no nasal polypi. Suppuration in the right maxillary antrum was diagnosed. A decayed first molar tooth was extracted and the socket perforated. Irrigation was carried out for eleven months very consistently, notwithstanding that the patient travelled a good deal. At the end of that time the condition appeared to be cured. It was not, however, until the patient had been syringing for nine months that he noticed a distinct change in the character of the secretion, which became at that time less purulent and of much thinner consistence.

In the following case, in which the discharge had apparently lasted for a similar time as in case A., irrigation did not prove satisfactory:—

CASE B. was a patient sent to me by Dr. Welsh. He had been conscious of discharge for nearly nine years from the left nostril. It was slightly

offensive. Suppuration in the left maxillary sinus was diagnosed, and the cavity was opened through the alveolus, and irrigation practised. There were no nasal polypi. After eighteen months the patient returned, expressing himself as tired of the treatment, which was not establishing a cure. The radical operation was performed, the mucous membrane being considerably altered. It is further interesting to note that in this case a second radical operation was found necessary, five weeks after the first, as the cavity had become reinfected by a septic focus of mucous membrane which had not been removed. The patient made an excellent recovery.

In the next case we have an example of a rapid cure by lavage, with a history of nasal discharge for at least one year:—

In Case C., a fœtid bad-tasting discharge was diagnosed as having its source in the left antrum. There were no nasal polypi. The cavity was opened through a diastema in the situation of the first molar tooth. Irrigation was carried out in the following way:—Twice daily for four weeks, once daily for the next four weeks, then every other day for two weeks, twice weekly for the next two weeks, then once during the following week,—in all a period of thirteen weeks. As no pus was visible at the end of the fifteenth week, and as the cavity, previously opaque to illumination, now illuminated fairly well, the obturator was shortened, and the alveolar track allowed to close. There was no recurrence of symptoms.

In the next case there was a history of nasal discharge for eighteen months, but the irrigation failed to cure the antral condition, owing to suppuration in the frontal sinus of the same side:—

Case D.—There were no nasal polypi; the left maxillary sinus was opened through the alveolus, and irrigation commenced; the pus was at first fœtid. For eight months this treatment was carried out more or less systematically, but at the end of that time the patient complained that he was no better, and that he constantly suffered from frontal headache, and a sense of fulness in the forehead on stooping. In this case the antrum apparently filled up rapidly, as it yielded a considerable quantity of pus on irrigation in the morning, and five or six hours afterwards an equally large quantity was again removed. In all probability it received the pus from the frontal sinus: this was found to be the case. Both cavities were therefore simultaneously treated by radical operation, and all the symptoms disappeared.

B. The Radical Operation

This operation consists in opening into the sinus, curetting its altered mucous lining, and dealing with carious or necrosed bone, should such be found, and then by appropriate after-treatment encouraging the formation of a new lining membrane. It is mainly in this way, though to some extent also by the filling up of the cavity with granulation tissue and its subsequent organisation, that an antrum thus treated, heals. It is unfortunate, perhaps, that entire obliteration of the cavity is not possible. During recent years, various procedures—some of which are merely old methods reintroduced—have been carried out with the object of putting the above principles into effect.

(*a*) *Opening through the Canine Fossa.*—The operation is greatly facilitated by administering the chloroform from a Junker's inhaler through a metal tube passed into the mouth, so that the operator's view is not interfered with, while the patient can be kept more continuously under the influence of the anæsthetic. It is advisable also to insert a gag between the teeth on the side opposite to the diseased antrum, and to have a number of throat sponges prepared for immediate use. The introduction between the cheek and posterior molar teeth of a sponge, which can be frequently changed, will be found of great assistance in preventing the blood from passing into the throat. The operator should also provide himself with long strips of gauze, for the purpose of controlling the hæmorrhage in the antral cavity. The upper lip having been everted, an incision is made down to the bone through the fold of mucous membrane between the lip and the alveolus. This incision is carried from the canine ridge outwards to the malar process of the superior maxilla; the periosteum is then raised, and the area of bone forming the canine fossa is thoroughly exposed. With the aid

of a chisel and mallet, a perforator, or a small trephine saw, the antral cavity is then entered. The opening may be enlarged by means of bone forceps, Zaufal's mastoid forceps being very useful for this purpose. Electro-motor burs are serviceable for enlarging and smoothing the bony edges of the wound. While reflecting the periosteum and removing the facial wall in an upward direction, care must be taken not to injure the infra-orbital nerve and artery, as they pass through the foramen of that name at a varying distance beneath the infra-orbital margin. The size of the opening made in the bone varies; some operators enlarge it, so that the interior of the cavity may be carefully inspected, and the little finger readily inserted in order to palpate its walls. Others, again, content themselves with a smaller opening, but the larger one is certainly to be preferred. Hæmorrhage is controlled, and the cavity dried by plugging; with the aid of good illumination from a mirror or electric forehead lamp, the antrum is inspected.

The altered mucous membrane is then scraped with a sharp spoon; it is very necessary that the different walls and angles of the cavity should come within the reach of the curette, so that no focus of disease is overlooked, a step which has a very important influence on the success of the operation. Special attention should be paid to the floor of the cavity. For purposes of curetting, sharp spoons, or ring knives which can be fixed at different angles, should be employed. I find the latter, mounted on a pliable stem which can be bent by the operator to suit each case, of great use. The hæmorrhage, which is usually pretty free at this stage, should now be controlled by plugging, and on the removal of the gauze a thorough inspection of the cavity should again be made, and any suspicious area dealt with. Care must be taken, while curetting the roof of the cavity and the angle between it and the facial wall, that the infra-orbital nerve is not injured in its bony canal; further, that the recess

concealed by the ridge of bone, in which this canal so frequently runs, must not be overlooked and diseased membrane left untouched (Plate V. Fig. 1).

Finally, the antrum is thoroughly dried; some swab the cavity with pure carbolic acid before lightly packing it with iodoform worsted or gauze; the end of the dressing is left just within the cut edges of the mucous membrane, which fall together when the lip is released from the retractor.

The after-treatment demands considerable care, and must be carried out with the greatest attention to surgical cleanliness. Two objects are aimed at, namely, the aseptic healing of the cavity and the closure of the wound between the antrum and the mouth. In order to diminish the risk of reinfection of the antrum, a small pad of wool or unprepared gauze wrung out of boracic lotion should be placed between the upper lip and the alveolus, so as to cover the wound. This should be changed three or four times daily after the patient has taken food, which should be fluid or semi-solid; at the same time the surface of the wound should be gently syringed with boracic lotion, while the mouth is repeatedly washed out. The packing is not removed until the fifth or sixth day if the temperature and local appearances do not indicate its earlier removal. The cavity is then inspected, and again plugged and re-dressed every third or fourth day, the plug being finally removed, and the wound allowed to close, at the end of the second week or later, when granulations line the cavity. The dressing is not painful if carefully done, and subjects the patient to very little annoyance. The sterilised iodoform worsted employed is preserved in corrosive sublimate (1-1000), which should be thoroughly wrung out immediately before insertion of the plug. To some patients the taste of iodoform is objectionable, but in these cases the double cyanide gauze can be substituted at the first dressing. It will be observed that the dry method

of treatment alone is adopted. Personally I have found this mode of treatment very satisfactory in a considerable number of cases, and have obtained good results with it. My experience does not agree with that of some, who have found the after-treatment most distressing to the patient, and the buccal wound a danger to the antral cavity. To one who has been syringing his antrum perhaps for months, the cessation of all further treatment on his own part, and the cure of the condition in a comparatively short time, come as a great relief. As regards the closure of the aperture between the antrum and the mouth, there is, as a rule, no difficulty, a permanent communication being rarely, if ever, established. The partial closure of the incision in the buccal mucous membrane by one or more stitches, either at the time of the operation or after the first or second dressing, will obviate this risk should it be feared. The alveolar track in which the obturator has been worn usually closes readily, but to prevent infection of the cavity from that source its lower end may with advantage be kept plugged with the obturator, or with gauze, for a few days after the operation. Preferably, however, the track is allowed to close some days before the radical treatment is carried out. Occasionally the surgeon meets with failure after curetting the cavity, even in cases uncomplicated by suppuration in one of the other sinuses upon the same side of the nose. The patient may experience a feeling of numbness in the lip and on the gum of the affected side as the result of division of sensory nerve branches.

b. Opening through the Canine Fossa, with a Counter Opening in the Inferior Meatus of the Nose (Caldwell,[1] Luc).—With a view to diminish or prevent the risk of reinfection of the sinus through the buccal wound, a modification of the previous operation is now practised by some. Its essential

[1] *New York Med. Journ.*, November 4, 1893.

feature consists in the immediate closure of the incision in the buccal mucous membrane, after establishing a large communication between the antrum and the nose. The opening in the canine fossa in the first instance is necessary, as the interior of the antral cavity cannot be properly dealt with through the anterior naris. With the preliminaries and the details of the operation as before, its main steps, as described by Luc,[1] are as follows:—After everting the upper lip, an incision commencing behind at the level of the first molar tooth is carried forward as far as the canine ridge. The soft parts are divided a few millimètres below the buccal fold between the alveolus and the cheek, so as to facilitate the introduction of the stitches at a later stage of the operation. The periosteum is then raised, and a large opening, sufficient to admit the finger, is made through the facial wall, care being taken to remove the bone up to the junction of the facial and nasal walls, that is, as far inwards as the canine ridge. By doing this, the artificial opening into the nose is more easily made. The cavity is carefully curetted and inspected, and then swabbed out with a strong solution of chloride of zinc (1 in 10 or 1 in 5), and temporarily plugged with iodoform gauze, so as to arrest the oozing of blood. The second stage in the operation is now carried out: the nasal chamber on the same side is first plugged with gauze, so as to avoid injury to the septum nasi. By means of the gouge, introduced through the canine opening, the antero-inferior portion of the nasal wall of the antrum is removed; an electro-motor bur will greatly facilitate this step in the operation. The nasal mucous membrane is dissected off along with the anterior half of the inferior turbinated bone. This insures the establishment of a large communication between the sinus and the nose. The antral cavity is again plugged

[1] "Leçons sur les suppurations de l'oreille moyenne et des cavités accessoires des fosses nasales," Paris, 1900.

from the mouth, and the end of the dressing passed through the naso-maxillary opening, for future extraction by this route. The incision in the buccal mucous membrane is now closed with catgut sutures threaded upon a slightly curved needle. This wound is probably healed upon the third or fourth day, but care must be taken in the interim to prevent the contact of food with it. The plug is extracted from the antrum through the nose four or five days after the operation. The use of the handkerchief may then be found sufficient for getting rid of any abnormal secretion in the cavity; it is found advisable, however, to wash it out through a curved cannula or Eustachian catheter during the succeeding four or six weeks. If, then, after an interval of seven days, the fluid is returned clear, the cure may be considered complete. This operation is not indicated when there is any coexisting sinus disease, or when antral suppuration is complicated with an atrophic rhinitis. The advantages claimed for it by the authors are to be found in the rapid closure of the buccal communication, and the avoidance of repeated plugging through the mouth. On the other hand, with due care and attention in the after-treatment by way of the mouth, risk of reinfection and inconvenience to the patient can be reduced to a minimum, and certainly the propriety of establishing a large permanent opening between the nasal and antral cavities is open to question.

II. TREATMENT OF CHRONIC SUPPURATION OF THE FRONTAL SINUS

When the treatment of this condition comes under consideration, there are—as in the case of the antrum—two methods open to discussion, namely, irrigation of the sinus through the natural orifice by way of the nose, and the radical treatment by an external operation. In order to effect a cure, in

the majority of cases it is necessary to remove all intranasal disease, so as to prevent reinfection of the sinus, to establish free drainage into the nose, and to restore the lining membrane of the sinus to a healthy condition. Further, these results must be brought about with the least possible disfigurement to the patient. Owing to the situation of the ostium frontale at the most dependent part of the cavity, the drainage from this sinus is, as a rule, good, and probably for this reason there is a greater tendency to spontaneous cure in cases of acute suppuration than in similar conditions of the antrum. When the chronic form is met with, it may therefore be right to assume that it is due to imperfect drainage, combined with an altered condition of the mucous membrane such as has already been described. It is undoubtedly the case that these changes are very frequently met with in the frontal sinus in chronic cases. Under these circumstances, we naturally ask ourselves how far imperfect drainage and polypi can be influenced by irrigation through the nose, and whether in any of these cases it is worth while to give this method of treatment a trial. It is true that occasionally a successful result is thus obtained, but far less frequently than in the case of the antrum. The disadvantages of the method appear to outweigh the isolated cases of successful treatment. Further, the existence of anatomical irregularities and incomplete subdivisions of the sinus interfere with satisfactory irrigation of the whole cavity, while it is difficult to deal thoroughly from the nasal side with the ethmoidal disease which is so frequently coexistent. Again, irrigation cannot be readily carried out by the patient himself. It is necessary, in a word, to condemn any attempt to enter the frontal sinus with a sharp instrument passed upwards from the nose. A perusal of Spiess'[1] paper dealing with this procedure, aided by the

[1] *Arch. f. Laryngol.*, Berlin, 1899, Bd. ix. Heft 2.

Röntgen rays, does not lead one to modify views previously held regarding the danger of this method. As the technique of the external operation still further improves, we shall cease to consider such points as those just referred to, and in all cases at once proceed to perform the radical operation.

When persistent headache, pain referred to the sinus, or localised swelling, indicate inefficient drainage, the operation should be urged upon the patient, so as to avoid the danger of orbital or intracranial complications. In proposing the external operation, it is only fair to point out to the patient that a slight scarring is inevitable, and that a certain amount of disfigurement may follow, though in many cases this is slight. The surgeon should himself bear in mind that it is sometimes necessary to perform a second operation, and that several fatalities have now been recorded, death being due to an acute septic infection of the cranial bones and meninges after operative interference. In all probability, in these cases imperfect drainage and incomplete removal of the diseased ethmoidal cells led to infection of the frontal diploë and extension to the cranial contents. With due care in carrying out the operation, such an unfortunate termination should be avoided.

A. TREATMENT BY LAVAGE THROUGH THE OSTIUM FRONTALE

Although this is not advocated here as a routine method of treatment, it is necessary for the sake of completeness to refer to the procedure. The preliminary steps consist in snaring all nasal polypi that may be present, and in removing the anterior portion of the middle turbinated bone. To carry this out, a pair of Walsham's nasal scissors or Grünwald's forceps are introduced, and, under the guidance of the eye, the attachment of the bone to the outer wall of the nose is

divided. This section is made horizontally from before backwards through the thin neck of the bone lying above its more expanded anterior extremity. The loop of a nasal snare is then passed along the incision thus made, and the portion included therein is removed. All polypi then brought into view must be dealt with, and by means of the punch forceps and the curette diseased ethmoidal cells are broken down, and the passage into the sinus still further opened up. More than one sitting is probably necessary to effect this. After an interval of a few days, an attempt should be made to pass the frontal cannula and wash out the sinus (*vide* Chapter V. p. 47). A weak solution of boracic acid is useful for this purpose, and daily irrigation of the cavity may be practised with it.

B. THE EXTERNAL OPERATION

It is very necessary, as a preliminary but important stage of the radical treatment, to thoroughly remove from the nose all diseased tissue that is accessible, along with the middle turbinated bone, some days prior to the major operation.

Both eyebrows are shaved and the skin of the forehead carefully disinfected on the evening before the operation. The removal of both eyebrows, even in unilateral affections, is mainly for cosmetic reasons, as equality in the new growth of hair is thus insured; occasionally, too, in the course of the operation, it has been found necessary to open both sinuses. It is unnecessary to interfere with the hair of the head, as during the operation it is covered with a sterilised or antiseptic towel. Boracic lotion alone should be employed during the operation, so as to avoid any injury to the eyes by the use of stronger solutions. A general anæsthetic is administered through a Junker's inhaler; throat sponges and a gag should

be held in readiness. Herbert Tilley[1] recommends plugging of the posterior nares in order to prevent the passage of blood into the larynx, but this procedure is not essential.

Very satisfactory access to the sinus, along with the least possible disfigurement, is obtained in most cases through the eyebrow incision. The incision is commenced at the inner end of the supra-orbital margin, at a point corresponding to the position of the fronto-nasal suture; thence it is carried upwards and outwards to the supra-orbital notch, following the curve of the bone. An incision of this length readily admits of the sinus being opened in the majority of cases. It can be prolonged outwards at a later stage if the size of the sinus should render this necessary. Should this still be found insufficient, a vertical cut may be made upwards from its inner end in the line of one of the natural furrows or wrinkles. It is difficult to avoid injury to the supra-orbital nerve and artery, even when the sinus is of average size. All the structures are divided down to the bone, and bleeding is arrested. The soft parts, including the periosteum, are then raised and pulled upwards by a blunt hook or small retractor. The portion of the anterior sinus wall thus exposed lies immediately above the root of the nose, and occupies the interval between the mesial plane of the forehead and the most internal part of the supra-orbital margin. If there is any doubt about the presence of a sinus, or its size, or the position of the intervening septum, the area above described offers the surest site for entering the cavity. The thickness of the bone varies in different cases, but it is readily removed with a small chisel and mallet. The mucous lining of the cavity then shows itself as a dark blue membrane, readily recognisable as such whether in a healthy or diseased condition. In this respect it presents a distinct contrast to the white appearance of

[1] *Lancet*, July 14, 1900.

the dura mater. It may be noted, further, that in the event of there being no sinus, the dura mater is not reached by chiselling until considerably more bone has been removed than that which usually constitutes the anterior wall of a sinus in the majority of European skulls. When the mucous membrane has been exposed, it is incised, and a bent probe is introduced, so that the extent of the cavity in its various directions and the position of the intervening septum may be definitely ascertained. Pus probably escapes from the sinus during this manœuvre. If the cavity is found to be a small one, the opening is only slightly enlarged, but if there is a considerable upward or outward extension of the sinus, more bone must then be removed, either with the chisel or with some form of cutting forceps. The supra-orbital margin, for cosmetic reasons, should not be interfered with, as a greater falling in of the soft part follows in consequence of this. Practice differs with regard to the amount of bone that is taken away, a point which will be dealt with later; it must, however, be borne in mind that a large sinus can be satisfactorily treated without interfering to any great extent with its anterior wall, thus greatly lessening the risk of future disfigurement.

After carefully mopping out the cavity with gauze, and inspecting its interior so far as is possible, the thickened and often polypoid lining membrane is curetted with the sharp spoon. The various curved instruments referred to under antral treatment are equally serviceable here. Careful attention must be directed to the investigation of all recesses and subdivisions of the cavity; this remark applies especially to the external angle of the sinus, where these anatomical irregularities more frequently occur. Failure to remove the disease from such areas may render the treatment abortive. The septum and the condition of the bony walls must also be examined, and any deficiency in them duly recognised. The frequent backward

extension of the sinus along the roof of the orbit must also be explored.

The next step in the operation, and one on which much of its success depends, consists in enlarging the ostium frontale and fronto-nasal passage, in order to establish a free opening into the nose, and at the same time to remove every trace of diseased mucous membrane not previously dealt with by intranasal treatment. This may be effected by means of sharp spoons of varying size; Herbert Tilley[1] employs a series of curved burs of progressive sizes for this purpose. The operator may find it expedient in the first place to pass a probe from the sinus into the nose, which serves, so to speak, as a pilot. The diseased anterior ethmoidal cells are then destroyed by curetting, and a large opening is made, through which the little finger may be passed. The cavity is thoroughly dried and carefully inspected, after which its interior may be swabbed with pure carbolic acid, and lightly packed through the forehead incision with iodoform worsted or gauze, or with Lister's double cyanide dressing. The end of the worsted is brought out through the lower extremity of the skin incision; the periosteum and soft parts are replaced, and the wound accurately sutured, with the exception of the small portion occupied by the end of the worsted strand. No drainage tube or strip of gauze is passed from the sinus into the nose. A superficial dressing and bandage, which necessitate the covering in of the eye at the same time, are applied.

The after-treatment is regulated by the temperature, and the appearance of the wound. It is advisable to remove the bandage in twenty-four or thirty-six hours in order to inspect the eye, as in one case I found that conjunctivitis had been accidentally induced by some irritating application during the operation. If the wound follows an aseptic course, the packing

[1] *Loc. cit.*

may be left *in situ* for seven or eight days, and then removed. The small aperture then readily closes, or healing may be assisted by the introduction of a suture. The stitches should be removed at the earliest opportunity, so as to avoid any future marking from this cause. The short, curved incision does not lend itself to the introduction of a subcutaneous suture.

Unfortunately, recurrence of suppuration in the sinus may take place, an undesirable result, which is probably due to its reinfection from the nose, or from failure to remove all the diseased lining membrane, or from overlooking some area of carious bone. In some cases it is possible, by opening up the wound, and by daily irrigation and packing of the cavity, to again establish an aseptic condition, but it may prove necessary to carry out a second, or even a third, operation before a successful result is obtained.

Several cases have now been recorded in which an acute osteo-myelitis of the frontal bone has resulted from surgical interference, followed by meningitis or a general septicæmia, terminating in death.

I have thus endeavoured to sketch the operation which is more or less successfully performed at the present time, and which appears to satisfy surgical requirements in the majority of cases. It closely resembles the method usually referred to as the Ogston [1]-Luc operation, although differing in some minor points of detail. The latter surgeon,[2] after packing the sinus, brings the lower end of the gauze plug into the nasal chamber, and completely closes the skin incision. This plug he removes through the anterior naris two or three days later. Walker Downie,[3] after bringing the outer end of the gauze strip through the opening in the bone, passes it through a small buttonhole incision made in the skin close to the reflection of the upper

[1] *Med. Chron.*, Manchester, 1884–85, vol. i.

[2] *Loc. cit.*

[3] *Glasg. Med. Journ.*, May, 1899.

eyelid, and concealed beneath the supra-orbital margin; the eyebrow incision is then completely closed. I have found this method satisfactory, permitting, as it does, accurate apposition of the edges of the wound, while the buttonhole is afterwards not visible. It possesses this disadvantage, however, that if the cavity should require to be repacked, this cannot be done through the buttonhole, and the reopening of the first incision is therefore necessary. Herbert Tilley [1] gradually removes the gauze plug, cutting off about three inches every third day, and finally removing the remainder when the cavity is completely lined with healthy granulations. The employment of a drainage tube passing from the sinus to the nose has now been practically abandoned by nearly all operators, the worsted or gauze plugging having been substituted. I would strongly urge that, after a radical operation upon the maxillary or frontal sinus, treatment by packing should be carried out, and that all irrigation should, if possible, be dispensed with.

Different methods of dealing with the anterior bony wall of the sinus must be briefly referred to. The question of the removal of bone is of considerable æsthetic importance, and must receive a due amount of consideration from the surgeon. Kuhnt [2] advocated and practised complete removal of the anterior wall. When the cavity is small and shallow, an attempt may be made to obliterate it by the apposition of the superficial soft parts against the posterior sinus wall, a procedure which is followed by a certain amount of depression of the skin surface. When the sinus is large and extends backwards along the roof of the orbit, it is impossible to completely obliterate it in this way, and the disfigurement which results from the removal of an extensive area of bone is considerable. The sex, age, and the feelings of the patient are factors which must be taken into account in reference to this point, while

[1] *Loc. cit.* [2] *Loc. cit.*

experience justifies us in promising, in a large number of cases, satisfactory results without the removal of the whole anterior osseous wall. Howard Lothrop[1] in one case turned down from this wall a flap of bone and periosteum, which he afterwards replaced. Jansen,[2] recognising the frequent association of ethmoidal suppuration, has removed the inferior wall of the frontal sinus, through an incision made immediately below and parallel to the supra-orbital margin. In this way more ready access to the ethmoid cells was obtained. Osteo-plastic operations have also been introduced by Czerny, Küster, and Winckler,[3] with the object of completely removing the disease with the minimum of disfigurement. Skin-grafting of the interior of the sinus by Thiersch's method will in the future probably play an important part in the after-treatment of these cases. Tilley[4] has recently reported a successful case of this kind.

When both frontal sinuses are affected, some operators enter each cavity through a mesial vertical incision, and if both sinuses are small, this single incision readily suffices. Others, again, unite the eyebrow incisions across the mesial plane, and from the centre of this carry a vertical cut upwards. In bilateral affections it certainly seems better to operate upon each cavity through a separate eyebrow incision. Two advantages may be claimed for this manner of procedure. The after-treatment of each sinus can in this way be carried out independently of the other, a point of some practical importance if one of the cavities should continue to suppurate; further, the scars are at the same time confined to the region of the eyebrow, as in the case of a unilateral sinus affection.

When the frontal and maxillary sinuses of the same side are affected, both should be dealt with at one operation, in order that every source of infection may be removed from the

[1] *Loc. cit.*
[2] *Loc. cit.*
[3] *Arch. f. Laryngol.*, Berlin, 1897, Bd. vii. Heft 1.
[4] *Loc. cit.*

nose at the same time. Should the surgeon deem it advisable to complete the operation in two stages, it is better to explore the higher sinus in the first instance, so as to prevent any reinfection of the antrum by discharge passing downwards from the untreated frontal sinus.

III. TREATMENT OF CHRONIC SUPPURATION IN THE ETHMOIDAL CELLS

In discussing the treatment of frontal sinus suppuration, we have already referred to the frequent coexistence of disease in the anterior ethmoidal cells, and have shown how the latter affection must be dealt with when thus associated. The treatment of ethmoid disease *per se* is conducted along similar lines, with this difference, however, that it is carried out entirely through the intranasal route. The general surgical principles involved consist in the establishment of free drainage and the removal of every focus of diseased mucous membrane; the possible existence of suppuration in one or more of the other sinuses must always be borne in mind and systematically dealt with, otherwise failure to cure the ethmoid affection will result. The method of operating will depend to a large extent upon whether the disease is limited or extensive. In the former case cocaine is applied, and, with the aid of good illumination, the polypi which are present are in the first instance snared, and the greater portion of the middle turbinated bone removed. At subsequent sittings the process of snaring, of punching and scraping diseased mucous membrane and bone, is repeated until the surgeon has satisfied himself, if possible, by careful inspection and probing, that every trace of disease has been removed. Owing to hæmorrhage which masks the field, and in some cases owing to the patient's inability to tolerate a prolonged sitting, several operations are

necessary, even in those cases in which the disease does not appear to be extensive. The ethmoidal region may be temporarily plugged with gauze so as to control bleeding, but it is not advisable, so long as foci of suppuration exist, to check the free exit of discharge by firm packing.

In the second group of cases, where the disease is extensive and appears to involve the whole ethmoid labyrinth, a more complete operation, carried out at one sitting and under a general anæsthetic, is recommended. The operation is conducted under such circumstances by the sense of touch, and not under the guidance of the eye. Lambert Lack,[1] who strongly advocates this line of procedure in suitable cases, examines the ethmoidal region with the finger, introduced both through the anterior and posterior nares. The middle turbinated bone is removed with the spokeshave, and large polypi by means of forceps. The lateral mass of the ethmoid is then thoroughly scraped away with a large ring knife, an instrument which he considers much more effective than the sharp spoon. From time to time the finger is introduced, so as to determine the presence of diseased areas of bone, and to define the limits of the healthy tissue, determined by its smooth, firm, and resistant feel. We scarcely require to emphasise the necessity of exercising the greatest care when working in proximity to the cribriform plate. At the end of the operation all hæmorrhage is arrested by packing the cavity with a strip of gauze soaked in glycerine-iodoform emulsion, which should be changed every second or third day, and the nose syringed. This radical procedure, which has been attended with very considerable success in Lack's hands, is advocated on the grounds that it is less irksome, tedious, and painful for the patient, and that more satisfactory results are thus obtained. Those cases of ethmoid disease which are associated with orbital phlegmon and

[1] *Trans. Laryngol. Soc. London*, December, 1900.

abscess, or with the formation of an orbital fistula, demand an external operation in addition to the usual intranasal treatment. In the latter case the fistula must be enlarged, and the communication with the ethmoid cells sought for. Where there is no external opening, the labyrinth may be entered through a curved incision closely resembling that employed in opening the frontal sinus, but which is prolonged downwards towards the inner canthus of the eye. By raising the periosteum along with the soft parts, the inner wall of the orbit is exposed. If a communication with the bone is found, it is opened up, the ethmoid cells curetted, and a free passage established with the nasal chamber. By the use of gauze pledgets the hæmorrhage may be satisfactorily controlled. After swabbing the cavity with pure carbolic acid, it is plugged with gauze, and the external wound is partially closed.

IV. TREATMENT OF CHRONIC SUPPURATION IN THE SPHENOIDAL SINUS

The removal of the middle turbinated bone, which has already been effected for diagnostic purposes, or which may have been removed in the treatment of ethmoidal disease, forms a necessary preliminary stage in the treatment of sphenoidal sinus suppuration. The subsequent steps should consist in the establishment of free drainage, and in the removal, as far as possible, of all diseased mucous membrane. While it is true that in a certain number of cases the natural opening can be catheterised, and the cavity in this way satisfactorily washed out, it must not be forgotten that the orifice is small, and is usually situated some distance above the floor of the sinus. Better drainage can therefore be established by breaking down the anterior sinus wall, a procedure which also permits of the subsequent introduction of

the curette and the scraping of the interior of the cavity. The operation is performed through the anterior naris under cocaine anæsthesia, and with the aid of good illumination. Hajek[1] introduces a small but strong hook into the sphenoidal opening, and so to speak tears down its anterior wall, the pieces of bone and mucous membranes thus partially detached being then removed with forceps. The same result may be obtained by means of a sharp spoon, and into the orifice thus enlarged one of the blades of a pair of punch forceps, as recommended by Grünwald, is introduced; portions of the bone are then rapidly punched out, and the opening considerably enlarged both downwards and laterally, the greater part of the anterior wall being in this way removed. The cavity is then packed with gauze for twenty-four hours. In the majority of cases a small opening tends to contract and close comparatively early. Should it be deemed advisable or necessary to scrape the sinus, the sharp spoon must be employed with care and mainly in a downward direction, so as to avoid any pressure upon the thin roof of the cavity. Indeed, in all the manipulations connected with diagnosis and treatment, due care must be exercised in dealing with the upper and outer walls of the sinus. The swabbing of its interior with pure carbolic acid, followed by irrigation at intervals, may greatly improve the patient's condition and lead to a permanent cure. Grünwald,[2] whose experience in the treatment of sphenoidal sinus disease is considerable, has obtained very satisfactory results. Several of his cases completely recovered in a few weeks, while in none of them did the period of treatment exceed four months. Jansen,[3] Luc,[4] and Furet[5] have opened the sphenoidal sinus through the antrum in cases complicated with disease in this

[1] *Loc. cit.*
[2] *Loc. cit.*
[3] *Trans. Internat. Med. Cong.*, Moscow, 1897.
[4] *Loc. cit.*
[5] *Arch. internat. de laryngol., etc.*, 1900, Bd. xiv.

cavity and in the ethmoidal cells. In the case reported by the last-named author, both sphenoidal sinuses were reached through the healthy antrum upon one side. By making a large opening in the canine fossa, and resecting the nasal wall along with portions of the middle and inferior turbinated bones, the anterior sinus wall may be exposed to view and then removed.

No attempt has been made in the preceding pages to enter into a detailed history of the gradual but progressive development of our knowledge of the surgery of the accessory sinuses of the nose. We have endeavoured rather to place before the reader a systematic and fairly complete account of the surgical anatomy of these sinuses and their relations to the nasal cavities, and at the same time to furnish him with a concise description of the clinical phenomena of suppuration.

The whole subject is one of very considerable interest and importance, not only to the surgeon who confines his attention to this branch of surgery, but alike to the general surgeon and to the physician. During recent years a wider recognition of the symptoms and signs which point to an inflammatory affection of one or more of these cavities, and a notable improvement in our methods of examination, have brought about greater precision in diagnosis, and have consequently placed treatment upon a more rational basis. A thorough knowledge of the anatomy of the nose and its neighbouring cavities is essential for a proper understanding of the various symptoms connected with suppuration. When we remember the many anatomical variations which are found in this region, we cannot fail to appreciate the necessity of thoroughly mastering the details connected with them.

A more intimate knowledge of the pathology of inflammation of the sinuses, especially with regard to the bacteriology of the affection, will probably still further assist us in our study of these conditions. Further improvements have yet to be effected in our methods of operating not only in connection with the posterior group of sinuses, but also in our treatment of the maxillary and frontal cavities. Every case should be carefully and systematically studied, so that no opportunity may be lost of adding to our knowledge of this branch of surgery.

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